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P327

Envirosafe Services of Idaho, Inc.  
Grand View, Idaho  
ESII Site B  
Site Characterization and Groundwater  
Monitoring Program  
February 1986  
Volume IA-Text

INSTRUCTIONS TO REPORT HOLDERS

This February 1986 report supercedes and replaces the original Site Characterization and Groundwater Monitoring submittals made in December 1983 and May 1985 as part of the original Part B permit application and all subsequent submittals and revisions to that document. Therefore, the entire text of the May 1985 submittal should be removed and replaced with this February 1986 submittal.

The appendix material has also been updated. Instructions for making the changes, additions, and deletions are noted below. Please note: The Table of Contents for this report shows the correct and current appendix format and contents. Please refer to it to confirm the changes.

APPENDIX MODIFICATIONS

<u>Section</u>	<u>Status</u>	<u>Comments</u>
<u>VOLUME I</u>		
<u>APPENDIX A</u>		
✓ Well and Boring Locations (Figure A-1)	Replace	Replace with new map (Figure E.3-1 in text)
Geologic Cross Sections (May 1985)	No change	No change in Appendix (new cross sections in text - Figures E.4-2, E.4-4, and E.4-5, and Plate 4-1)
Soil Boring Logs (Figures A-5 and A-6)	No change	
Well Logs and Reports for Deep Artesian Well	No change	
Soil Boring and Rock Core Logs, B Series	Addition	Insert new logs
✓ Soil Boring and Rock Core Logs, D Series	Addition	Insert new logs
✓ Soil Boring and Rock Core Logs, MW Series	Addition	Insert new logs
Soil Boring and Rock Core Logs, WW, SW, and PCB Series	Addition	Insert new logs
Interim Report--Status of Subsurface Drilling and Groundwater Data	No change	

<u>Section</u>	<u>Status</u>	<u>Comments</u>
<u>APPENDIX B</u>		
Well Construction Summary (Table B-1)	Replace	Replace with updated table (Table E.3-2 in text)
Well and Piezometer Construction Details (Figures B-1 through B-9) and B-10 through B-12	Replace and Addition	Replace with updated figures (B-1 through B-9) and new figures (B-10, B-11, B-12)
<u>APPENDIX C (in Volume IV)</u>		
Geophysical Logs	Addition	Insert five new logs in box
<u>VOLUME II</u>		
<u>APPENDIX D</u>		
Packer Test Summary (Table D-1)	No change	
Calibration of Pressure Test Equipment and Pressure Test Results	No change	
Pumping Test Reports and Well Recovery Plots	Replace	Discard entire section; replace with new material (new section titled Aquifer Test Data and Plots)
Response of a Finite-Diameter Well to an Instantaneous Charge of Water	Discard	
McWhorter Plots	Replace	Discard entire section; replace with new material (new section titled Aquifer Test Data and Plots)
<u>APPENDIX E</u>		
Potentiometric Surface Maps and Flow Lines (Figures E-1, E-2, E-3, and E-4) - Only two, no labeling	Addition	Insert new Figures E.5 and E.6 ( <u>note base map changes</u> )
Well Measure Point Descriptions and Elevations	Replace	Replace with updated table

Section	Status	Comments
Water Level Data	Replace	Discard section; replace with new material; and add updated Hydrograph section
Barometric Efficiency Data	No change	
Hydrographs	Replace	Discard section; replace with new material; and combine with updated Water Level Data section

APPENDIX F

Monitoring Well and Piezometer Sampling (Table F-1)	Replace	Replace with updated table, now titled Analytical Data (Table E.4-8 in text)
Ion Balance Summary (and Figures F-1 and F-2)	Addition	New section
Common Ion Analytical Laboratory Reports	Addition	New section
Method Detection Limits for Statistical Analysis; Data Summaries - January 1984 through November 1984	Replace and Addition	Replace Detection Limits for Trend Plots table with new table; insert updated Abbreviations for Trend Plots (from second to last section of Appendix F); insert all trend plots that follow Abbreviations table (currently second to last section of Appendix F); separate Data Summaries - January 1984 through November 1984 from Trend Plots with new divider sheet and cover page
Trend Plots - Key Parameters vs. Time	Addition	New section
ETC Data Management Status Report, December 1984	No change	
ETC Data Management Status Report, March 1985	Discard	Contains data only through March 1985

*Checks*

*- Trend plots - Selected Parameters*

<u>Section</u>	<u>Status</u>	<u>Comments</u>
✓ ETC Data Management Status Report, December 1985	Addition	Incorporates March 1985 data and additional data through December 1985 ✓
✓ ETC Technical Reports - Silo Investigations, Soils and Water Analytical Data	Replace	Replace with complete set (data through June 1985) ✓
Conductivity Data <i>Don't have</i>	No change	
Conductivity and Barometric Pressure Graphs <i>Don't have</i>	No change	
✓ Abbreviations for Box and Whisker Diagrams and Trend Plots	Replace	Replace with updated Abbreviations for Trend Plots table; discard <u>Method Detection Limits</u> table; and move trend plots (second to last section of Appendix F) to precede Data Summaries ✓ <i>Removed one one still exists confirm next</i>
✓ Trend Plots - Selected Parameters Shown on Map	Addition	Insert cover page; move section (11" x 17" sheets, currently the last section of Appendix F) to follow Data Summaries

VOLUME III

APPENDIX G

Finite Resources B-Site Interim Status RCRA Closure and Post Closure Plans and Cost Estimates	No change	
Geology in the Vicinity of the EnviroSAFE Hazardous Waste Site (Site B) Near Grand View, Idaho	No change	
Report of Geotechnical Investigations, ESI Hazardous Waste Disposal Site, Grandview, Idaho	No change	
Geophysical Logging, ESII Site B, Grandview, Idaho	No change	
The Earth Technology Corporation, Geophysics Department, Letter; Geophysical Survey, ESI, Site B, Grandview, Idaho	No change	

<u>Section</u>	<u>Status</u>	<u>Comments</u>
Northern Engineering and Testing, Inc., Technical Reports	Addition	Insert additional technical report at end of Appendix G
<u>APPENDIX H</u>		
Sample Volumes, Containers, Preservatives, and Holding Times for Selected Analytical Parameters (Table 1)	Replace	Replace with updated cover page and updated Table 1 (now titled Sampling and Preservation Procedures for Detection Monitoring)
Quality Assurance/Quality Control Procedures	No change	
Chain-of-Custody Form (CC1)	No change	
Methodologies	No change	
Sample Volumes, Containers, and Preservatives for Indicator Parameters	Replace	Replace with updated cover page
ETC Technical Report for Appendix 8	No change	
Summary of ETC Proposal for Appendix VIII Analysis for Conversion Systems	No change	
<u>APPENDIX J</u>		
Priority Pollutants Data Reports	Addition	Insert cover page
<u>APPENDIX K</u>		
Supplemental Report	Discard	

BOT513/006



# Envirosafe Services, Inc.

115 GIBRALTAR ROAD, HORSHAM, PA. 19044  
(215) 441-5924 , 5938

February 24, 1986

Mr. Charles E. Findley  
Director  
Hazardous Waste Division  
U.S. Environmental Protection Agency  
Region X  
1200 Sixth Avenue  
Seattle, WA 98101

Re: Envirosafe Services of Idaho, Inc. - ID No. IDD073114654  
Submission of Section E, Part B Permit Application

Dear Mr. Findley:

Enclosed is Section E of Envirosafe Services of Idaho, Inc.'s (ESII) Part B Permit Application for ESII's facility 10 miles west of Grand View, Idaho (Site "B"). This document, entitled ESII Site B Site Characterization and Groundwater Monitoring Program, a revised and updated version of the May 10, 1985 document. From discussions with Mr. Stamnes of Region X, it was decided to resubmit Section E to incorporate the data and interpretations resulting from work done subsequent to the May 10, 1985, document. We have incorporated into the document additional geotechnical, hydrogeological and water quality data as well as the substance of two interim or supplemental documents entitled Supplemental Analysis of Hydrochemical Conditions at ESII Site B (November, 1985) and Interim Progress Report - Site Characterization - Proposed Trench 14 Area, ESII Site B (November, 1985) previously submitted to EPA.

We consider this document to be complete in accordance with the requirements of 40 CFR 264 and 270 for site characterization and groundwater monitoring program design.

Pursuant to 40 CFR 270.11, I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

Mr. Charles E. Findley  
February 24, 1986  
Page 2

Please contact Mr. Robert Buller or me if you have any comments or questions on this submission.

Sincerely,



Lee C. Cleveland  
Sr. Vice President, Environmental Affairs

LCC/dtg

Enclosure

cc. L. W. Stokes, PhD, Idaho Health & Welfare (w/Attach)  
Congressman Larry E. Craig (w/o Attach)  
Owyhee County Commissioners (w/Attach)  
C. E. Ashby, Jr., ESI (w/o Attach)  
L. C. Haack, ESII (w/Attach)

**ESII Site B**  
**Site Characterization and**  
**Groundwater Monitoring**  
**Program**

**Envirosafe Services of Idaho, Inc.**  
**Grand View, Idaho**

U.S. EPA I.D. No. IDD073114654



February 1986

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*New text on  
Vadose*

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Well and Boring Locations (Figure A-1)

Geologic Cross Sections (May 1985)

Soil Boring Logs (Figures A-5 and A-6)

Well Logs and Reports for Deep Artesian Well

Soil Boring and Rock Core Logs, B Series

Soil Boring and Rock Core Logs, D Series

Soil Boring and Rock Core Logs, MW Series

Soil Boring and Rock Core Logs, WW, SW, and PCB Series

Interim Report--Status of Subsurface Drilling and Groundwater Data

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Well Construction Summary (Table B-1)

Well and Piezometer Construction Details (Figures B-1 through B-12)

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Abbreviations for Trend Plots

Trend Plots

Data Summaries - January 1984 through November 1984

Trend Plots - Selected Parameters Shown on Map

Trend Plots - Key Parameters vs. Time

ETC Data Management Status Report, December 1984

ETC Data Management Status Report, December 1985

ETC Technical Reports - Silo Investigations, Soils and Water Analytical Data

Conductivity Data

Conductivity and Barometric Pressure Graphs

APPENDIX G

Finite Resources B-Site Interim Status RCRA Closure and Post Closure Plans and Cost Estimates

Geology in the Vicinity of the Envirosafe Hazardous Waste Site (Site B) Near Grand View, Idaho

Report of Geotechnical Investigations, ESI Hazardous Waste Disposal Site, Grandview, Idaho

Geophysical Logging, ESII Site B, Grandview, Idaho

The Earth Technology Corporation, Geophysics Department, Letter; Geophysical Survey, ESI, Site B, Grandview, Idaho

Northern Engineering and Testing, Inc., Technical Reports

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APPENDIX H

Sample Volumes, Containers, Preservatives, and Holding Times  
for Selected Analytical Parameters (Table 1)

Quality Assurance/Quality Control Procedures

Chain-of-Custody Form (CC1)

Methodologies

Sample Volumes, Containers, and Preservatives for Indicator  
Parameters

ETC Technical Report for Appendix 8

Summary of ETC Proposal for Appendix VIII Analysis for  
Conversion Systems

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Priority Pollutants Data Reports

BOT420/054

*Appendix I?  
-not listed*

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- ✓ E.1-1 Location of ESII Site B Facility
- NO ✓ E.1-2 Site Plan
- NO ✓ E.1-3 Site Topographic Map
- ✓ E.2-1 Major Surface Water Drainages in the Vicinity of Site B
- ✓ E.2-2 Topographic Setting of ESII Site B
- ✓ E.2-3 Location Map of Known Water Wells
- ✓ E.2-4 Stratigraphy of the Western Snake River Plain
- ✓ E.2-5 Location of Shallow System Groundwater Resource Areas Within the Oreana Hydrologic Subunit
- ✓ E.2-6 Hydrogeologic Cross Section A-A'
- ✓ E.2-7 Location Map for Hydrogeologic Cross Section A-A'
- ✓ E.3-1 Well and Boring Locations
- ✓ E.4-1 Line of Geologic Section Projected Along Predominant Structural Attitude
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- ✓ E.4-4 Generalized Hydrogeologic and Geophysical Cross Section  
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- ✓ E.4-6 Point Transmissivity and Maximum Point Velocity Values
- ✓ E.4-7 Water Level and Barometric Pressure Changes
- ✓ E.4-8 Potentiometric Surface Map and Flow Lines for the Upper Aquifer (for November and December 1985)

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- E.5-1 List of Analytical Parameters
- E.6-1 One and Two Tailed Critical t Values at the  
0.05 Level of Significance

✓ EPA GROUNDWATER MONITORING CHECKLIST

<u>EPA Outline</u>		<u>ESII Submittal</u>
E-1	Exemption from groundwater protection requirements	--
E-1a	Surface impoundment	--
E-1b	Waste piles	--
E-1c	Landfill	--
E-1d	No migration	--
E-2	Interim status period groundwater monitoring data	E.5.2
E-3	Aquifer identification	E.4.2
E-4	Contaminant plume description	E.4.3.4.1
E-5	Detection monitoring program	E.6
E-5a	Indicator parameters, waste constituents, reaction products to be monitored	E.6.2
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E-5a(2)	Behavior of constituents	E.6.2
E-5a(3)	Detectability	E.6.2
E-5b	Groundwater monitoring program	E.6
E-5b(1)	Description of wells	E.6.5.2, E.6.5.3, E.6.7.2
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E-5c(1)(b)	Sampling frequency	E.6.2

✓ EPA GROUNDWATER MONITORING CHECKLIST (continued)

EPA Outline		ESII Submittal
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E-5c(1)(d)	Background values	E.6.5.3
E-5c(2)	Plan for establishing groundwater quality data	E.6.5.2
E-5c(2)(a)	Well location	E.6.5.2
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E-5d(2)	Sample preservation and shipment	E.6.8.1.2, E.6.8.1.3.1
E-5d(3)	Analytical procedure	E.6.8.1.4
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E-5d(5)	Additional requirements for compliance point monitoring	E.6
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E-5d(6)	Annual determination	E.6.6
E-5d(7)	Statistical determination	E.6.8.2
E-5d(7)(a)	Statistical procedure	E.6.8.2.1, E.6.8.2.2, E.6.8.2.3
E-5d(7)(b)	Results	E.6.8.2.4

BOT420/D.101

✓ RCRA REGULATIONS CROSS REFERENCE

<u>Federal Regulation</u>	<u>ESII Submittal</u>
264	E.1, E.1.5, E.6.2, E.6.3, E.6.4, E.6.8.1.1.1
264.90	--
264.91	E.6.1
264.91 (a)	--
264.91 (a) (1)	E.6.1
264.91 (a) (2)	--
264.91 (a) (3)	--
264.91 (a) (4)	--
264.91 (b)	--
264.92	E.6.1, E.6.4
264.93	--
264.94	--
264.94 (a)	E.6.4
264.94 (b)	E.6.4
264.95 (a)	E.4.2
264.95 (b)	--
264.95 (b) (1)	--
264.95 (b) (2)	--
264.96	--
264.97	--
264.97 (a)	E.6.5.2, E.6.5.3
264.97 (a) (1)	E.6.5.3
264.97 (a) (2)	E.6.5.2
264.97 (b)	E.6.5.3
264.97 (c)	E.6.5.2, E.6.5.3
264.97 (d)	E.6.8.1
264.97 (d) (1)	E.6.8.1.1.3
264.97 (d) (2)	--
264.97 (d) (3)	E.6.8.1.4
264.97 (d) (4)	E.6.8.1.3
264.97 (e)	--
264.97 (f)	E.6.6, E.6.8.1.1.1
264.97 (g)	--
264.97 (g) (1)	E.6.3
264.97 (g) (2)	--
264.97 (g) (3)	--
264.97 (g) (4)	E.6.3
264.97 (h)	E.6.3
264.97 (h) (1)	E.6.8.2.1
264.97 (h) (1) (i)	E.6.2, E.6.8.2
264.97 (h) (1) (ii)	E.6.3, E.6.8.2.2
264.97 (h) (2)	--
264.97 (h) (2) (i)	--
264.97 (h) (2) (ii)	--
264.98	E.6.1, E.6.5.2
264.98 (a)	E.6.2
264.98 (a) (1)	--

RCRA REGULATIONS CROSS REFERENCE (continued)

<u>Federal Regulation</u>	<u>ESII Submittal</u>
264.98(a) (2)	--
264.98(a) (3)	--
264.98(a) (4)	--
264.98(b)	E.6.5.1, E.6.5.2
264.98(c)	E.6.3
264.98(c) (1)	--
264.98(c) (2)	E.6.3
264.98(c) (3)	E.6.5.1, E.6.5.3
264.98(d)	E.6.2, E.6.3
264.98(e)	E.6.6
264.98(f)	--
264.98(g)	--
264.98(g) (1)	--
264.98(g) (2)	--
264.98(h)	--
264.98(i)	--
264.99	--
264.100	E.6.1
264 Subpart F	E.1.2, E.1.3, E.5.1, E.5.2.2, E.6.1, E.6.3
265	E.1, E.6.1, E.6.3
265.92	E.5.1.1, E.5.2.1
265.92(a) (1)	E.5.1.1.1.3
265.92(a) (3)	E.5.1.1.4
265.92(a) (4)	E.5.1.1.3
265.92(b)	E.5.2.2
265.92(b) (1)	E.5.2.1
265.92(b) (2)	E.5.2.1
265.92(b) (3)	E.5.2.1
265.92(d) (2)	E.5
265.92(e)	E.5.1.1.1.1
265 Subpart F	E.5.1.1.2, E.6.5.2
270	E.1.2, E.6.4
270.14(c)	--
270.14(c) (1)	--
270.14(c) (2)	E.4, E.4.2, E.4.2.3, E.4.2.4.1, E.4.2.4.2
270.14(c) (3)	E.1
270.14(c) (4)	--
270.14(c) (5)	--
270.14(c) (6)	--
270.14(c) (6) (i)	--
270.14(c) (6) (ii)	--
270.14(c) (6) (iii)	--
270.14(c) (6) (iv)	--
270.14(c) (7)	--
270.14(c) (8)	--

## EXECUTIVE SUMMARY

Envirosafe Services of Idaho's Site B is a 120-acre RCRA Subtitle C hazardous waste treatment, storage, and disposal facility located in Owyhee County, Idaho. Over the time period September 1983 to December 1985, a hydrogeologic characterization study was performed at Site B to delineate the nature of subsurface geotechnical, hydraulic, and hydrochemical conditions for the purpose of developing an appropriate groundwater monitoring system. The study included the drilling of 52 test borings and the installation of 34 test wells at various locations across the site. Information from 10 borings installed by the Air Force in 1958 and from 16 geotechnical test borings installed between 1981 and 1983 was also used. Supplementary evaluative procedures included the geophysical logging of 34 test borings and the performance of 23 borehole packer and 14 aquifer pump tests. Laboratory geotechnical, mineralogical, and chemical analysis programs, and the development of a site-specific geochemical model were also performed.

The results indicated that saturated zones are present beneath Site B at depths ranging from 140 to 220 feet. Two low-yielding, fine-grained, and finely bedded water-bearing zones, referred to as the "upper" and "lower" aquifers, have been identified. Although designated as "aquifers" in this investigation for monitoring purposes, these water-bearing zones would not be classified as aquifers in the traditional sense because of their low-yield capacities. The lower aquifer consists of 30 to 40 feet of sandy silt and silty clay within which is a cumulative thickness of 4 feet of thin, fine-grained silty sands in beds ranging from less than one-sixteenth inch to about one foot thick. The upper aquifer section consists of 80 to 90 feet of sandy silt and silty

clay. There are 3 to 8 cumulative feet of thin, fine-grained silty sand seams ranging from less than one-sixteenth inch to 1-1/2 feet thick within this section. The saturated thickness of the upper aquifer beneath the site varies from zero to 60 feet. The upper and lower aquifers are separated by a continuous clay zone that ranges from 20 to 30 feet in thickness.

Figure 1 presents a diagrammatic cross section of the stratigraphy and water-bearing zones beneath Site B. Across the northern half of the site, the upper aquifer functions as the uppermost aquifer, as shown on Figure 1. Southward and at progressively higher elevations along a 2- to 4-degree structural dip, the upper aquifer becomes unsaturated. This phenomenon occurs at approximately the center of the site. South of this trend, the lower aquifer functions as the uppermost aquifer. The lower aquifer is saturated beneath the entire site area.

Groundwater velocity in the upper aquifer ranges from 12 feet to 82 feet per year and averages about 47 feet per year. In the lower aquifer, groundwater velocity ranges from 2 feet to 13 feet per year and averages 7 feet per year. The direction of flow in both zones is generally eastward. Recharge to these aquifers occurs offsite to the northwest (upper aquifer) and to the southwest (lower aquifer). The potential for recharge from onsite infiltration is very low and represents a negligible source of water to the upper aquifer.

Groundwater supplies in the local and regional areas are obtained from a deep, areally extensive artesian system. This system is encountered at depths in excess of 1,000 feet. The uppermost water-bearing strata identified beneath Site B are not part of this deeper artesian system. The groundwater

NORTHEAST

SOUTHWEST

SITE LOCATION (APPROX)

GROUND LEVEL

BRUNEAU FORMATION  
50± GRAVELS

GLENN'S FERRY FORMATION  
100± FLUVIAL SANDS AND CLAY

BEDDED FINE SANDS WITH SILT AND CLAY  
CONFINING ZONES

UPPER AQUIFER (3' TO 8' CUMULATIVE SAND THICKNESS)

INTERMEDIATE CLAY (CONFINING ZONE)

LOWER AQUIFER (4' CUMULATIVE SAND THICKNESS)

THICK BEDDED CLAY (CONFINING ZONE)

SATURATED THICKNESS  
0-60'

TOTAL THICKNESS  
80-90'

20-30'

15'

POTENTIOMETRIC SURFACE

NOTE:  
GROUNDWATER FLOW DIRECTION IS INTO THE DRAWING (EAST). DIP IS EXAGGERATED FOR ILLUSTRATIVE PURPOSES.

FIGURE 1  
DIAGRAMMATIC CROSS SECTION  
UPPER AND LOWER AQUIFERS  
(NOT TO SCALE)

development potential for the upper and lower aquifers is considered to be unfeasible to poor, based upon a comparison of site transmissivity data with U.S. Bureau of Reclamation groundwater development criteria. The transmissivity data range from 2 to 33 square feet per day for the upper aquifer, and from less than one to 3 square feet per day for the lower aquifer. These findings indicate that the uppermost water-bearing strata encountered beneath Site B are not a significant groundwater resource for the area. The strata are important, however, because they could potentially serve as migration pathways, a topic that has been addressed in the Site B detection monitoring program proposed for the site.

Water quality and hydraulic flow regime data support the finding that the upper and lower aquifers are geologically and hydraulically separate from each other. The results of the investigation show:

1. A 20- to 30-foot-thick clay stratum physically separates the upper and lower aquifers.
2. Portions of the clay stratum separating the upper and lower aquifers are unsaturated.
3. Laboratory-measured vertical permeabilities of the clay stratum separating the two aquifers range from  $10^{-6}$  cm/sec to  $10^{-8}$  cm/sec.
4. Potentiometric levels in the upper and lower aquifers differ.
5. Horizontal hydraulic gradients and groundwater velocities in the upper and lower aquifers differ.

6. The natural-ion inorganic water chemistries of the two aquifers differ. The water quality of the upper aquifer is of a calcium-magnesium/sulfate-bicarbonate type, while the lower aquifer is of a sodium-bicarbonate type.

Geologic data obtained during the investigation have revealed the presence of a finely bedded sequence of unsaturated fine-grained silty sand and silty clay within the upper aquifer section immediately above the saturated portion of the upper aquifer. This zone is 20 to 80 feet thick and is continuous across the entire site. To the north, where the upper aquifer is saturated, the fine-grained zone functions as an overlying confining layer. To the south, this fine-grained zone, within which the upper aquifer sands exist, is unsaturated media within the vadose zone.

Above the upper aquifer section are 120 to 140 feet of unsaturated sands, silts, and gravels. The gravels are clayey and are typically 50 feet thick. The sand and silts are fine to medium grained and contain periodic dense clay layers up to one foot thick. The clay layers gradually dominate from about 120 feet to the top of the upper aquifer section. The strata become increasingly clayey and contain thin sandy zones. The unsaturated portion of the upper aquifer section contains thick silt and clay beds, with thin sandy stringers and occasional fine-grained silty sandbeds less than one foot thick. The total vadose zone ranges from 140 to more than 220 feet thick.

The clays within the unsaturated (vadose) zone are composed of predominantly kaolinite and illite. The zeolite minerals chabazite and clinoptilolite are present in the clays above and within the upper aquifer. The presence of zeolites is

very advantageous because they effectively filter organic molecules from water.

Investigative data have not revealed the presence of any faults, fractures, or joints in any portion of the sedimentary units investigated in the study area. Secondary horizontal or vertical pathways of flow were not detected at this site. Where present in the region, faults typically provide vertical pathways for water to move up from deeper artesian aquifer systems. Water movement up faults is a significant source of recharge to the shallow sediments in the general area of the site.

A degree of spatial variability was observed in the inorganic ion hydrochemical data obtained during the characterization study. Increases in upper aquifer sulfate and calcium values were observed in a predominantly downgradient direction. The presence of an active pyrite-controlled geochemical redox cell is the source of the ion variability. A conceptual geochemical model, similar to those used to evaluate uranium "roll front" redox deposits, was developed and explains the observed hydrochemical patterns as a naturally occurring phenomenon. Mineralogical data support the hydrochemical redox model and provide additional confirmation that vertical recharge is not occurring at this site.

The analytical data collected from the RCRA monitoring wells on a monthly basis and from the test wells sampled during the course of the two-year hydrogeologic investigation have detected no evidence of hazardous constituents passing the site boundaries. As a result, a detection monitoring program has been proposed for the site. This detection monitoring program has been developed to monitor groundwater quality in the only potential pathway of groundwater flow identified during the course of the site characterization study: the

uppermost aquifer. As an added "early warning" system, a vadose zone monitoring network has also been proposed.

BOT513/004

## E.1 INTRODUCTION

The purpose of this document is to provide a complete and thorough characterization of the hydrogeologic setting of Envirosafe Services of Idaho's (ESII) Site B near Grand View, Idaho, and to propose a groundwater monitoring program responsive to the physical characteristics of the site and the operational characteristics of the facility. In the site characterization, the groundwater flow characteristics have been thoroughly delineated, and the subsurface geotechnical properties necessary to design a responsive groundwater monitoring program have been identified.

In conducting the investigation of site characteristics, five criteria were evaluated because of their importance for location acceptability:

1. Site characterization
2. High hazard and unstable terrains
3. Ability to monitor
4. Protected lands
5. Groundwater vulnerability

With the completion of the site characterization investigation, it can be concluded that:

1. The inherent geologic, hydrologic, and pedologic features of the site and location at large have been fully characterized. Enough strategically placed borings have been installed to enable ESII to consistently predict subsurface information.
2. The site geology provides a stable foundation for the engineered features of the facility, and there

are no inherent features for which protective measures cannot be designed, such as seismism, faulting, volcanism, landslides, or land subsidence.

3. All potential groundwater flow paths in the uppermost aquifer along which potential contaminants could migrate have been characterized, and representative groundwater quality can be (and is being) monitored.
4. The location of the facility does not conflict with any federally protected land resource values. *Bonds of prey*
5. The facility is not within a vulnerable groundwater setting.

The site characterization has established that the site is indeed "monitorable" based on four criteria:

1. The "uppermost aquifer" has been identified and the rate and direction of groundwater flow has been identified as required in Section 270.14(c)(3).
2. Groundwater pathways for potential contaminant migration have been thoroughly described.
3. Background monitoring well sites have been identified, and background water quality is known.
4. Suitable downgradient monitoring well sites exist, and a large amount of downgradient groundwater quality data are available.

The goal of the Part 264 regulations is to provide long-term protection by preventing the migration into the environment

of hazardous constituents from a facility during the operating life and a post-closure care period and by minimizing migration after closure. The primary focus is the protection of groundwater.

The groundwater resources and their protective features have been studied extensively at this site and are thoroughly characterized in this document. The features that contribute to the protection of groundwater at this site are as follows:

1. The climate is such that recharge to the uppermost aquifer beneath the site is considered to be extremely unlikely. Precipitation is low and the net evaporation is very high. Even when a large or prolonged precipitation event occurs, it would evaporate out of the shallow soil layers before it could infiltrate toward the water table.
2. There is typically 140 to 220 feet of unsaturated material between the disposal units and the top of the uppermost aquifer.
3. There is a 20- to 90-foot-thick layer of low-permeability bedded sand, silt, and clay material directly above the saturated portions of the upper aquifer.
4. There is a massive clay layer 20 to 30 feet thick between the upper and lower aquifers and beneath the lower aquifer. Thus, the upper and lower aquifers are hydraulically isolated from each other and from the underlying deep regional artesian aquifer.

5. Groundwater in the upper aquifers is moving slowly enough to allow adequate time for detection and remedial response measures, if necessary.

Proof of the success of the natural systems in protecting the groundwater resources is that no evidence of hazardous waste contamination has been found at any of the wells located on the downgradient edge of the site, even though these wells have been sampled monthly for more than 2 years for an extensive list of natural and manmade chemical parameters indicative of hazardous waste constituents and supplemented with groundwater quality testing done specifically for this investigation. This list and sampling frequency is far in excess of that identified in either Part 265 or Part 264 regulations.

Another means of evaluating the suitability of the site is through the use of the DRASTIC model. DRASTIC (Depth to water, [net] Recharge, Aquifer media, Soil media, Topography [slope], Impact of the vadose zone, and Conductivity [hydraulic] of the aquifer) is a standardized system published by EPA (EPA/600/2-85/018, May 1985) for evaluating groundwater pollution potential using hydrogeologic settings. Each of the seven characteristics mentioned above is given a weighted value as follows:

	<u>Weight</u>
Depth to water table	5
Net recharge	4
Aquifer media	3
Soil media	2
Topography	1
Impact of the vadose zone	5
Hydraulic conductivity of the aquifer	3

Ranges and ratings for the ESII site, when compared to the DRASTIC model, are as follows:

*Check  
Assume!*

DEPTH TO WATER

<u>Range (feet)</u>	<u>Rating</u>
0-5	10
5-10	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1

Weight: 5  
ESII Site Rating: 1

NET RECHARGE

<u>Range (inches)</u>	<u>Rating</u>
0-2	1
2-4	3
4-7	6
7-10	8
10+	9

Weight: 4  
ESII Site Rating: 1

AQUIFER MEDIA

<u>Range</u>	<u>Rating</u>	<u>Typical Rating</u>
Massive Shale	1-3	2
Metamorphic/Igneous	2-5	3
Weathered Metamorphic/Igneous	3-5	4
Thin Bedded Sandstone, Limestone, Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	9-10	10

Weight: 3  
ESII Site Rating: 5

SOIL MEDIA

<u>Range</u>	<u>Rating</u>
Thin or Absent	10
Gravel	10
Sand	9
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Nonshrinking and Nonaggregated Clay	1

Weight: 2  
 ESII Site Rating: 4

TOPOGRAPHY

<u>Range (percent slope)</u>	<u>Rating</u>
0-2	10
2-6	9
6-12	5
12-18	3
18+	1

Weight: 1  
 ESII Site Rating: 9

IMPACT OF VADOSE ZONE MEDIA

<u>Range</u>	<u>Rating</u>	<u>Typical Rating</u>
Silt/Clay	1-2	1
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with Significant Silt and Clay	4-8	6
Metamorphic/Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	8-10	10

Weight: 5  
 ESII Site Rating: 4

HYDRAULIC CONDUCTIVITY

<u>Range</u> <u>(GPD/FT<sup>2</sup>)</u>	<u>Rating</u>
1-100	1
100-300	2
300-700	4
700-1,000	6
1,000-2,000	8
2,000+	10

Weight: 3  
ESII Site Rating: 2

The equation for determining the DRASTIC Index is:

$$D_{RW} + R_{RW} + A_{RW} + S_{RW} + T_{RW} + I_{RW} + C_{RW} = \text{Pollution Index}$$

Using this equation, the pollution index for the, ESII site is:

$$(1)(5) + (1)(4) + (5)(3) + (4)(2) + (9)(1) + (4)(5) + (2)(3) = 5 + 4 + 15 + 8 + 9 + 20 + 6 = 67$$

According to the DRASTIC document, the ESII site is located within the Columbia Lava Plateau hydrologic setting. As the number generated is only comparable to other sites in the same hydrologic setting, its value is only relative, not absolute. However, based upon overall site suitability, the possible range of pollution potential is from a worst case of 230 to a best case of 23. This indicates that on an overall rating scale, nationwide, this site would be very highly rated. That is, its pollution index would be very low.

*Previous Submittal*

In December 1983, ESII submitted the original site characterization/groundwater monitoring section (Section E) for ESII's Site B as part of the Part B permit application. In response to deficiency comments received on the original

document, a revised document entitled ESII Site B Site Hydrogeology and Groundwater Monitoring was submitted on January 31, 1985. A supplement to this document was submitted in March 1985 as Appendix K to provide additional data that became available after the January 1985 document was prepared. In subsequent meetings between ESII and EPA-Region X, additional hydrogeological information about the site was requested by EPA. As a result, a document, dated May 1985, including all data collected and all data analyses performed during the course of these investigations, was submitted. Subsequent to the May 1985 submittal, two additional supplemental reports, Supplemental Analysis of Hydrochemical Conditions at ESII Site B (November 1985) and Interim Progress Report--Site Characterization--Proposed Trench 14 Area, ESII Site B (November 1985) were prepared and submitted in response to additional questions from EPA and its consultants. In order to provide a comprehensive, well-organized document, the May 1985 submittal has been revised and supplemented with the additional reports previously described.

*Parade*  
This report, ESII Site B Site Characterization and Groundwater Monitoring Program (February 1986), supercedes and replaces the original Site Characterization and Groundwater Monitoring submittal made in December 1983 as part of the original Part B permit application and all subsequent submittals and revisions to that document.

#### E.1.1 OVERVIEW OF THE ESII SITE B FACILITY

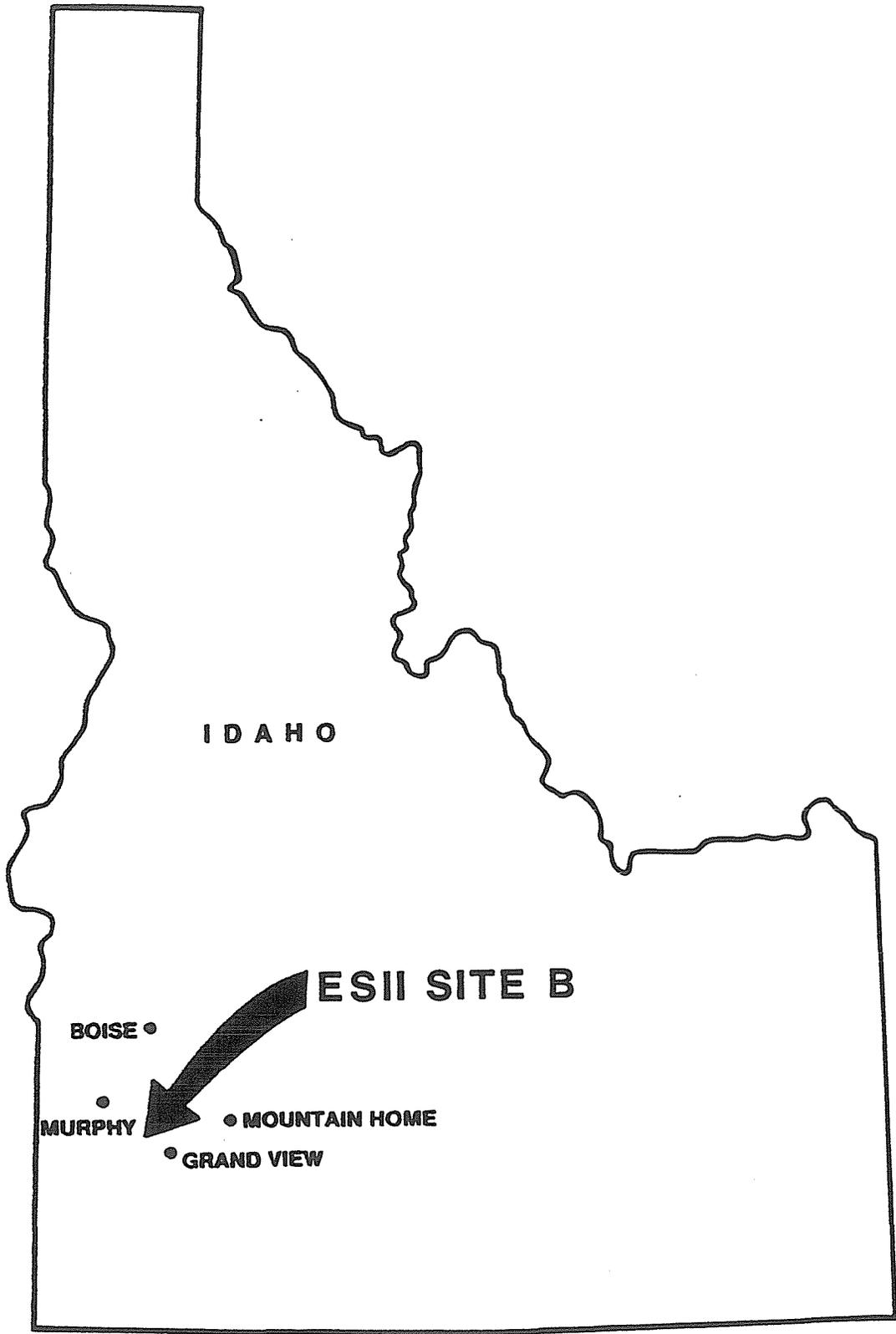
The Site B waste management facility (also referred to in this report as "the site" or "the facility") is located in Section 19, Township 4 South, Range 2 East, approximately 10 miles west of Grand View, Owyhee County, Idaho. The site is owned and operated by Envirosafe Services of Idaho, Inc.

(ESII), a subsidiary of Envirosafe Services, Inc. (ESI) of Horsham, Pennsylvania. Currently, the site occupies a land area of approximately 120 acres. Figure E.1-1 denotes the location of the facility.

The site was formerly a United States Air Force Titan missile defense site, constructed in the late 1950s and early 1960s. In 1972, the site was purchased from the Air Force and converted to a hazardous waste disposal facility by another owner/operator. During the interval prior to ESII's ownership, the three 160-foot-deep missile silos and ancillary structures present on the site were used as waste repositories. A number of shallow waste burial trenches (10 to 20 feet deep) were also constructed during that period. In 1981, the site was purchased by ESI. Currently, the site is operated by ESII as a RCRA Subtitle C waste treatment, storage, and disposal facility.

The Part B permit application provides information about the operating history of the site prior to being purchased by ESI; gives a description of ESII's present and past waste management programs at the site, including engineering design information for all waste management facilities and treatment processes; and provides an identification of all RCRA-regulated hazardous wastes that are managed at the facility. Much of this information was also disclosed in ESII's Part A permit application, submitted to EPA-Region X in 1981. These sources should be referred to for detailed information. A brief overview of ESII's waste management services at Site B is provided below.

The facility handles both hazardous and nonhazardous wastes. The hazardous materials are classified as such because of their RCRA-defined ignitable, reactive, corrosive, or toxic properties. The materials are stored and treated onsite,



IDAHO

BOISE •

MURPHY •

• MOUNTAIN HOME

• GRAND VIEW

ESII SITE B

FIGURE E.1-1  
LOCATION OF ESII  
SITE B FACILITY



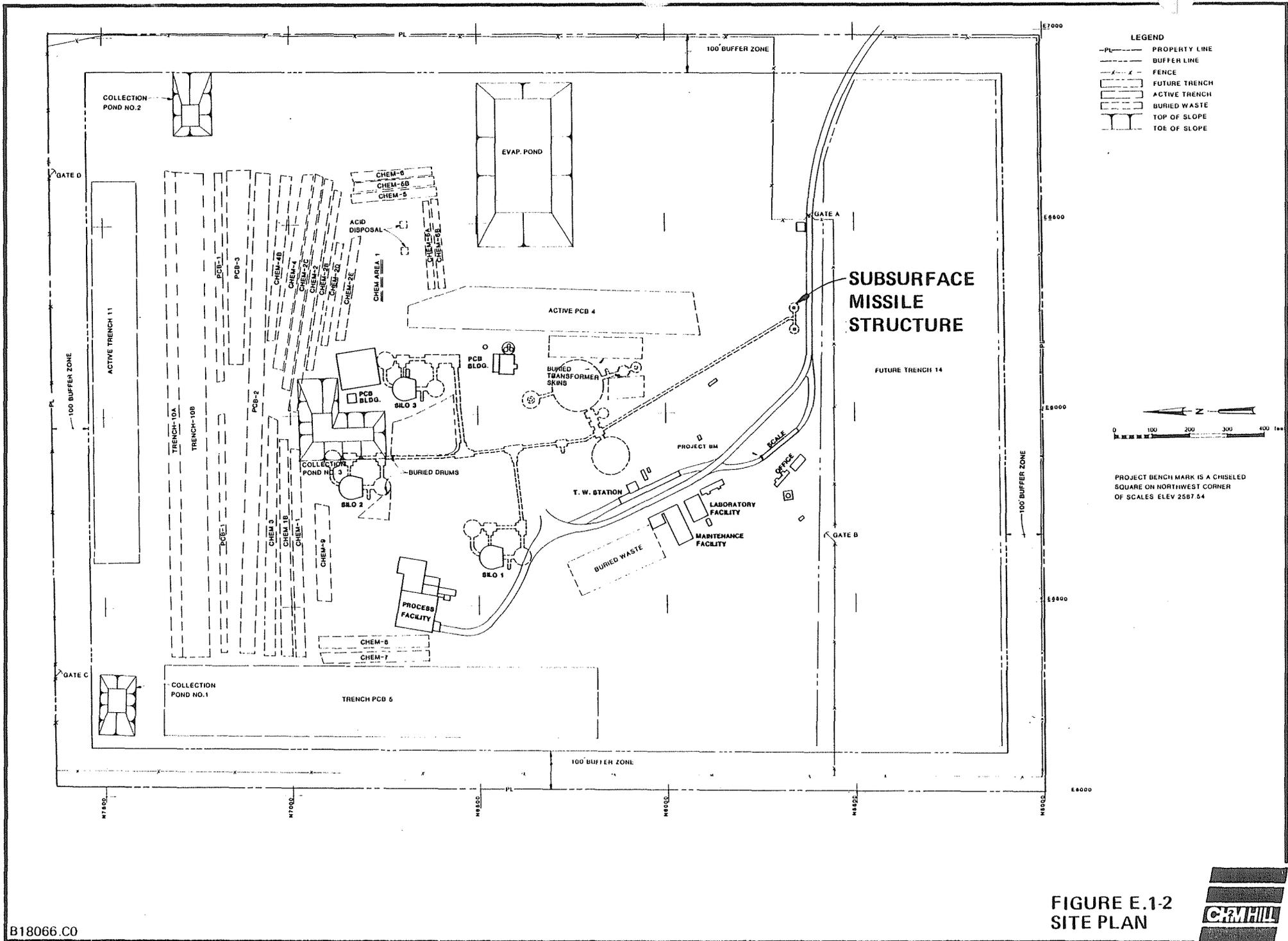
followed by disposal using landfill burial. Historically, the site has received bulk and drummed liquid wastes for treatment and disposal. Liquid wastes were stabilized with native soils and landfilled in shallow trenches. Currently, only solid wastes and stabilized PCB oil with less than 500 ppm PCB are disposed of in the trenches. Approximately 7 acres of burial trenches currently are dedicated to disposal activities at the facility. The active remaining life of the facility is projected to be 16 years.

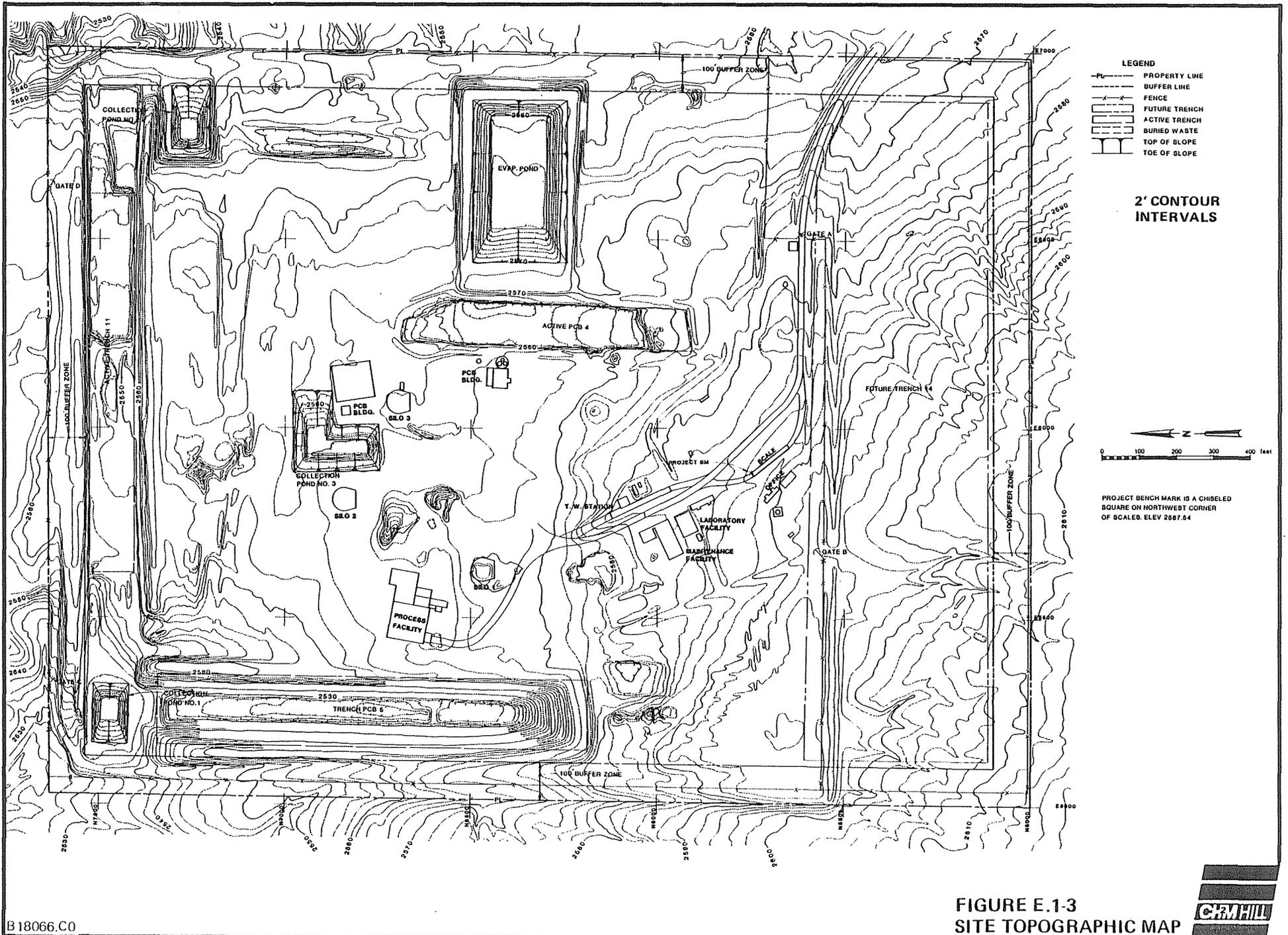
All wastes managed at the facility are accepted by ESII in strict accordance with RCRA's Hazardous Waste Manifest System. An onsite laboratory is used for waste identification and classification purposes. Segregation of wastes for storage, treatment, and disposal is accomplished in accordance with compatibility criteria as identified by the waste classification effort and the site's Waste Analysis Plan.

Figure E.1-2 is a plan view map summary of past, current, and future disposal areas at Site B. Also shown are the locations of principal support structures such as process buildings, office and maintenance facilities, and waste storage areas. In addition, a 100-foot buffer zone surrounding the facility is shown on the figure. The outside edges of the buffer zone denote the boundaries of the Site B property line; in total, approximately 120 acres of land are included within this boundary. Figure E.1-3 is a 2-foot contour interval topographic map of the facility.

#### E.1.2 PROJECT OBJECTIVES

The requirements for site characterization and groundwater monitoring programs that must be implemented at permitted hazardous waste management facilities are provided in 40 CFR 270 and 40 CFR 264 Subpart F of the RCRA regulations. As





described in these requirements, adequate site characterization of a facility's subsurface environment is necessary before a groundwater monitoring program can be proposed. In accordance with the requirements of Subpart F, the objective of the investigations was:

1. To delineate the physical nature and hydraulic characteristics of the subsurface environment present beneath Site B
2. To examine the rates and directions of flow in the uppermost aquifer
3. To examine hydrochemical patterns observed in the site groundwater and to relate those patterns to geochemical processes occurring in the subsurface
4. To identify whether past RCRA waste disposal operations have affected groundwater quality
5. To develop sufficient hydrogeologic information to support the design of a groundwater monitoring program

#### E.1.3 PROJECT SCOPE

The hydrogeologic and subsurface geotechnical studies that are discussed in this report were conducted from September 1983 to December 1985. Background information gathered since September 1983 indicated that the uppermost aquifer at the site is contained within a series of low-yielding, fine-grained, and finely bedded sediments, with depths to water approximately 180 feet below the ground surface. A principal element of the work effort has been the development of specialized subsurface drilling, logging, and hydraulic testing

techniques that would overcome the complexities of investigating a deep, low-yielding groundwater system. Conventional testing techniques and routine drilling and sampling methods were found to be inadequate for the needs of the study because of the depth limitations and low-yield characteristics of the aquifer.

In brief, the investigative program involved the following major elements:

Boring Program

52 test borings were drilled at the site to determine the nature of subsurface conditions and to identify the water-bearing zones present. 13 of the borings were drilled using undisturbed continuous coring techniques, and 36 borings were drilled using hollow stem auger, air rotary, or modified bucket auger techniques. Information from 26 additional test borings drilled by the Air Force in 1958 and for geotechnical foundation data was also used in this investigation.

Geophysical Logging

30 of the test borings were geophysically logged, several more than once, using a combination of natural gamma, gamma-gamma density, neutron, resistivity, spontaneous potential, caliper, and temperature techniques. The geophysical program was used as a supplement to the continuous core and geologic logging activities

in the overall interpretation of subsurface conditions.

#### Packer Tests

23 borehole packer tests were performed to provide initial estimates of hydraulic conductivities and to aid in the identification of water-bearing zones.

#### Well Installation

34 of the borings were completed as test wells to provide information on groundwater flow direction and rate, and on groundwater quality. 15 of the wells are proposed as permanent stations for long-term RCRA monitoring activities under 40 CFR 264 Subpart F.

#### Piezometer Installation

Five of the test borings were converted to small-diameter, dual-level piezometers and two wells were equipped with small-diameter piezometers above the well screens to provide information on vertical head distributions throughout the site.

#### Pump and Slug Tests

14 single-hole aquifer tests were performed using pumping or instantaneous slug withdrawal methods. The tests were conducted to identify aquifer transmissivities and hydraulic conductivities and were performed in both the upper and

lower aquifers. Special analytical methods for low-permeability materials developed by researchers were investigated and used in the analysis of the aquifer tests.

Water-Level Measurements

Periodic water-level measurements were obtained in all wells to confirm the direction of groundwater flow and to identify hydraulic gradients present beneath the site. Supplementary continuous water-level measurements were obtained at three wells over intervals as long as 2 months.

Continuous Conductivity and Temperature Measurements

Automated, continuous measurements of these two parameters were made at two wells to identify the time-related variability of total dissolved solids content and temperature of the groundwater.

Grain-Size Distribution Analysis

The grain-size distributions of 85 soil and aquifer samples were determined to aid in the geologic classification of materials and the estimation of hydraulic conductivities.

Laboratory Geotechnical Tests

A laboratory geotechnical program was implemented to examine the index properties of 78 core samples collected from three core-holes. Laboratory permeabilities

⊖  
were determined on 32 of the samples.

### Mineralogy

A total of 50 samples of the aquifer sands and confining clays were submitted for the determination of whole-rock mineralogy by X-ray diffraction methods and 16 samples were submitted for determination of Total Organic Carbon (TOC) and for whole rock evaluation. These data were used to develop and verify the hydrochemical model described for the site.

### Geochemical Modeling

Conceptual geochemical models were developed and tested to help explain inorganic hydrochemical patterns observed in the groundwater.

### Literature Search

A review of pertinent literature available from the U.S. Geological Survey, the Idaho Department of Water Resources, and others was conducted to delineate regional geologic and hydrologic conditions.

*Complete modeling  
Vadose drilling*  
*Review*  
The hydrogeologic studies performed at ESII Site B have been conducted in a phased manner in an effort to evaluate initial conceptual models of site conditions. This report reflects the phased nature of the project and in so doing supercedes and replaces earlier documents submitted in support of ESII's RCRA Part B permit application. Earlier submittals bearing the same title as this document were dated December 1983,

January 1985, and May 1985. In addition to these principal documents, several interim task completion reports have been submitted to EPA-Region X during the course of the investigations.

The current report includes the results of field and laboratory studies that were conducted prior to and including December 1985. Subsequent to the May 1985 submittal, additional activities and data collection efforts were performed at the request of EPA-Region X to verify and refine the concepts developed in that and earlier reports. The overall interpretations and conclusions regarding site conditions presented in the May 1985 report have not changed, however, as a result of this additional work.

Following the May 1985 submittal, a series of meetings were held with EPA-Region X to present the findings of work in progress and to develop a suitable course of action for further work. An important aspect of the meetings was the collaborative development with EPA of appropriate field procedures and evaluative methodologies that were used to clarify or resolve the few remaining interpretations of the physical data. The current submittal reflects these collaborative developments and incorporates comments provided by EPA-Region X review team members, as well as the supplemental report submitted to EPA in November 1985.

#### E.1.4 SUPPLEMENTAL INVESTIGATIONS

In November 1983, an Agreed Order was developed between EPA-Region X and ESII to investigate the magnitude and extent of subsurface soil and groundwater impacts that may have resulted from the historical disposal of waste materials in the three abandoned missile silos. Efforts to determine the physical configuration and integrity of the silos have been implemented

through a records search and actual drilling and sampling programs. When the results of the silo investigations obtained to date provide additional useful or supplementary insights into the nature of hydrogeologic conditions, they are discussed in this report.

#### E.1.5 REPORT ORGANIZATION

This report is organized into six major sections. Section E.1 provides an overview of the site and a summary of the hydrogeologic investigations performed. Section E.2 describes the regional geologic and hydrogeologic characteristics of the area. The investigative methods utilized during the study are provided in Section E.3. In Section E.4 the findings of the site-specific geologic, hydrogeologic, and hydrochemical investigations are presented, and the uppermost and next lower aquifers beneath the site are identified and described in this section. In Section E.5 the interim status water quality monitoring program and data are reviewed. Finally, in Section E.6 the proposed RCRA Part 264 Detection Monitoring Program for the ESII Site B facility is presented and discussed in detail.

This report contains material prepared independently and jointly by ESI and their consultant, CH2M HILL. Sections E.2 through E.4 were prepared by CH2M HILL as a scientific document to characterize the hydrogeologic setting of the site, both regionally and site specific. The conclusions of the site characterization were used by ESI to prepare Section E.6, Detection Monitoring Program. ESI and CH2M HILL collaborated on the Executive Summary and Sections E.1 and E.5.

BOT494/032

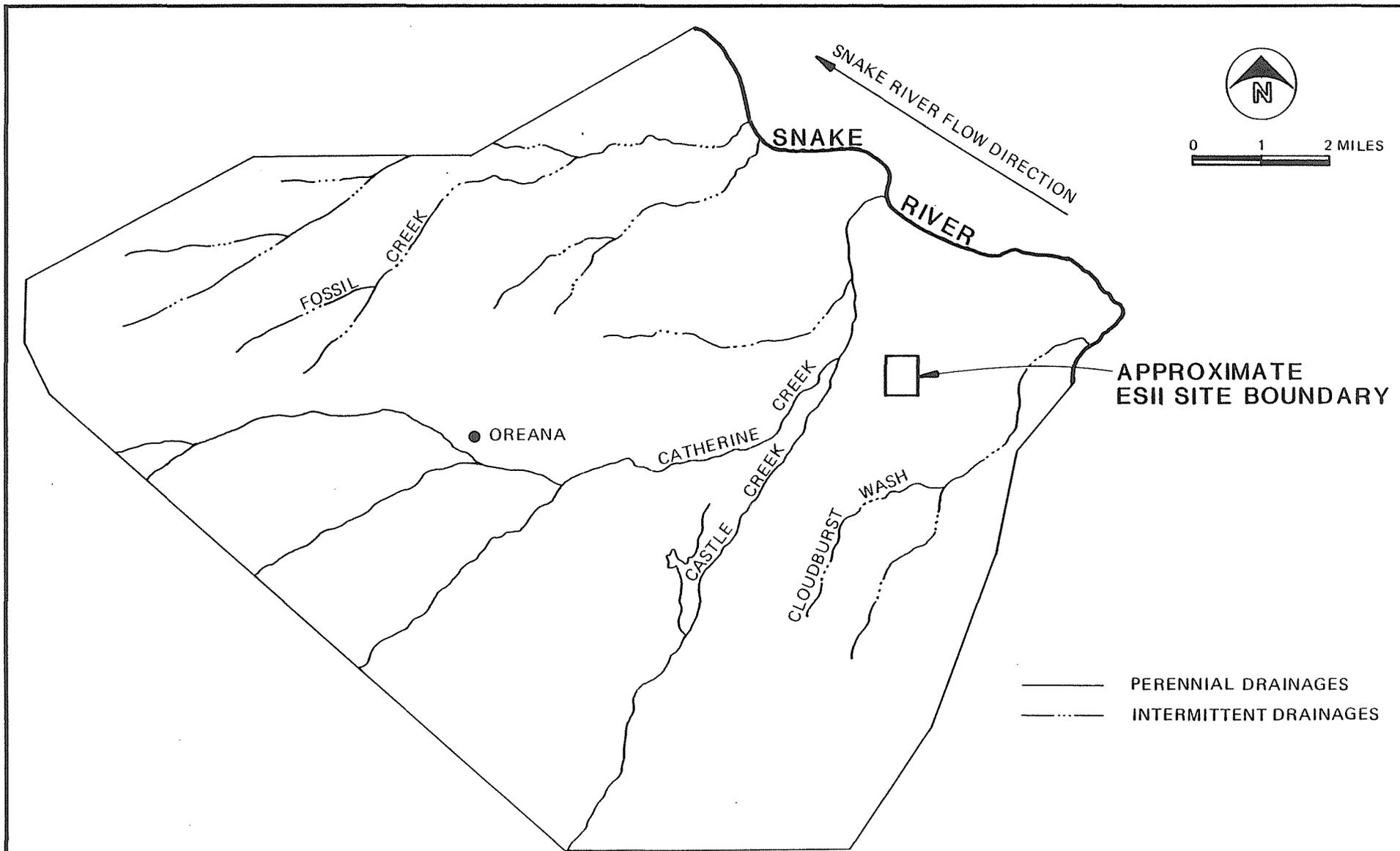
## E.2 REGIONAL SETTING

### E.2.1 PHYSIOGRAPHY

ESII Site B is situated in the western portion of a 20,000-square-mile physiographic unit known as the Snake River Plain. The plain extends from the vicinity of Aston, Idaho, to north of Ontario, Oregon. The Snake River Plain is approximately 350 miles in length and varies in width from 25 to 75 miles.

The physiographic setting of Site B is typified by the setting of northern Owyhee County, a 2,300-square-mile area investigated by Ralston and Chapman (1969). The northern Owyhee County area is a subunit of the Snake River Plain, about 100 miles long and 25 miles wide, located south of and roughly parallel to the Snake River. This area contains four principal geographic features: the Owyhee Mountains, the Owyhee Highland, the Snake River Canyon, and a lowland area between the Snake River and the highland. The Owyhee Mountains rise above 8,000 feet; the highland area is about 6,000 feet in elevation; and the Snake River is at an elevation of about 2,320 feet. ESII Site B lies within the lowland area at an elevation of between 2,525 and 2,635 feet. This area is about 25 miles northeast of the base of the Owyhee Mountains.

Figure E.2-1 shows the location of Site B relative to major surface water drainages in the area. The Snake River, which flows to the northwest, lies approximately 2.5 miles northeast of the site and is the most prominent water resource of the area. The site is about 250 feet in elevation above the Snake River flood plain, which locally extends outward approximately one-quarter to one mile along either side of the river.



SOURCE:  
 RALSTON AND CHAPMAN (1969)  
 OREANA HYDROLOGIC SUBUNIT

B18066.C0

FIGURE E.2-1  
 MAJOR SURFACE WATER DRAINAGES  
 IN THE VICINITY OF SITE B



Castle Creek, a perennial stream that flows northward to the Snake River, lies approximately one mile west of Site B. Cloudburst Wash, a small ephemeral (flows intermittently) stream, lies about 2 miles to the east of Site B and also empties into the Snake River. Most of the site is located within the drainage basin of Castle Creek. The eastern margin of the site falls within the drainage basin of Cloudburst Wash.

Figure E.2-2 depicts the topographic setting of the Site B area. The area is characterized by badlands-type topography and exhibits varied relief. Major topographic features of the area include several prominent buttes, remnant basaltic cinder cones, and canyons cut by the Snake River.

Vegetation in the area is typical of a semi-arid environment. The lowland area within which the site is located is inhabited by low brush and grasses, including sagebrush, rabbit brush, wheat grass, and cheat grass. Land use in the area consists of undeveloped rangeland and some limited irrigated agriculture. Nearly all the crops grown in the area must be irrigated, although some dryland forage is grown. Irrigation water in the area is derived from the Snake River, from tributary surface water diversions, and from groundwater. In general, the region is sparsely populated.

#### E.2.2 CLIMATE

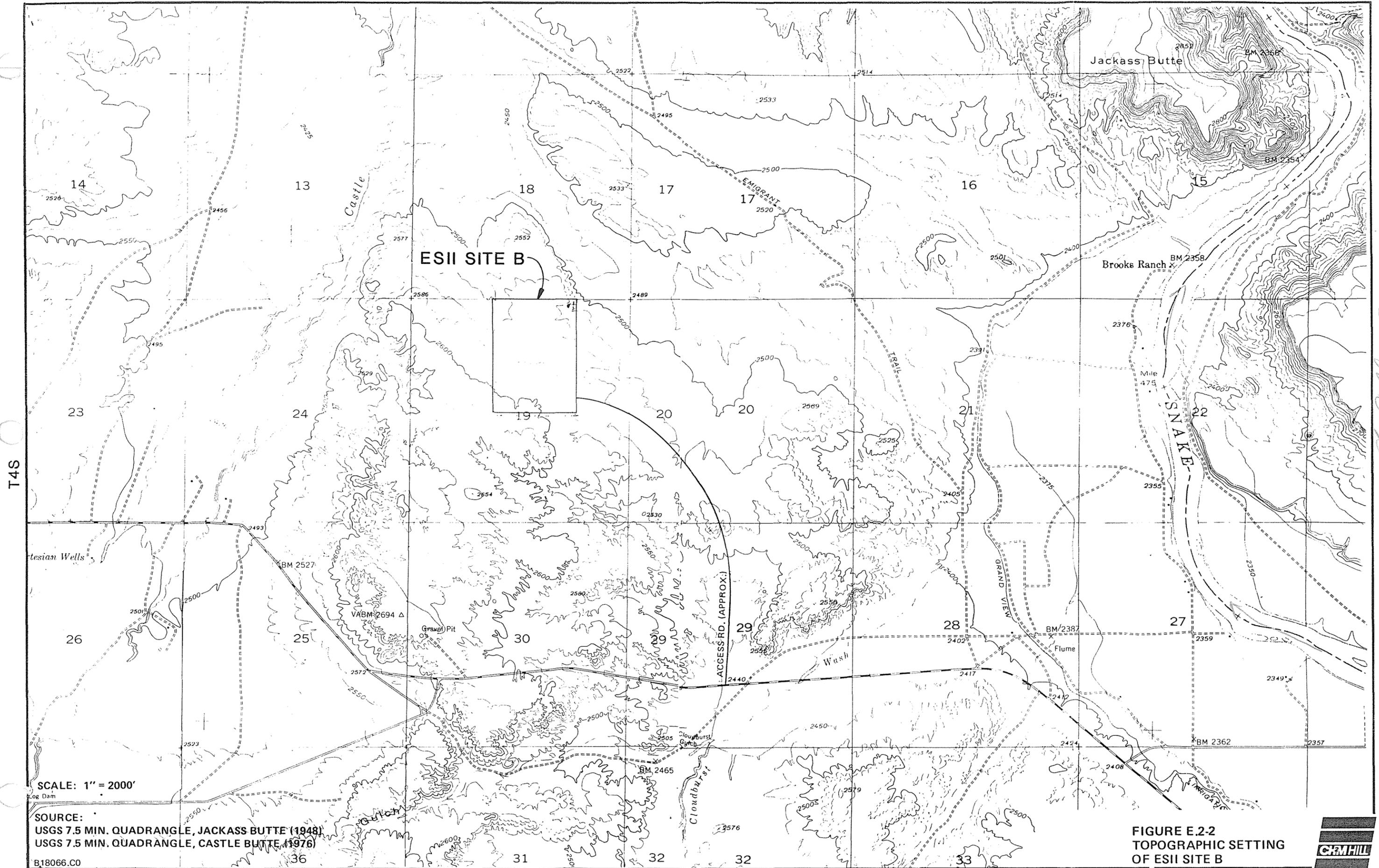
The site area is characterized by relatively mild year-round temperatures and low precipitation. The semi-arid western portion of the Snake River Plain has one of the highest annual average temperatures in the state, 52°F, and receives an average 10 inches of rain a year.

*add average at site for period of record*

Located some 300 miles from the Pacific Ocean, the area is influenced by prevailing westerly maritime winds via the

R1E

R2E



*add direction arrows*

SCALE: 1" = 2000'

SOURCE:  
 USGS 7.5 MIN. QUADRANGLE, JACKASS BUTTE (1948)  
 USGS 7.5 MIN. QUADRANGLE, CASTLE BUTTE (1976)

B18066.C0

FIGURE E-2-2  
 TOPOGRAPHIC SETTING  
 OF ESII SITE B



Columbia River and Snake River valleys. This influence is most noticeable during the winter, with greater average cloudiness, frequency of precipitation, and mean temperatures.

In the Snake River Plain, monthly mean temperatures of 32°F or lower persist from December through February. The diurnal range in temperature is lowest during the winter because of increased cloud cover. Conversely, from March to November, the temperatures range from -5°F to 110°F.

Over a 29-year period the average total precipitation at the Grand View U.S. Weather Bureau Station, located 10 miles east of the site, was 7.3 inches. For a 32-year period, the average temperature was 51.6°F. The precipitation in this area is evenly distributed from November through June, with only a minor amount falling during the summer. Evaporation averages 79.5 inches per year.

*add ESI site data for period of record, (wind rose)*

*New fig*

*Remember figures or add on Fig 2.0*

### E.2.3 REGIONAL WELL INVENTORY

Figure E.2-3 presents the results of a records search for known water wells in the area. Sixteen wells were identified within an approximate 2-mile radius of Site B. On this figure, the depths of the wells and the zones where groundwater was first encountered (if available from the records) are noted. The majority of the wells are generally deep and, as discussed in Section E.2.6, derive groundwater from an areally extensive, deep artesian groundwater system.

### E.2.4 REGIONAL GEOLOGY

Several investigators have been active in the delineation of the geology of the area. Malde and Powers (1962), Littleton and Crosthwaite (1957), Anderson (1965), and Ralston and Chapman (1969) have been active at the regional scale.



Benfer (1984) mapped the local geology in the vicinity of ESII Site B. Benfer's full report is included in Appendix G.

#### E.2.4.1 STRATIGRAPHY

The regional geology of the area is dominated by the 5,000 feet of sedimentary and interspersed basaltic lava deposits that accumulated in the Snake River Plain over a basement of thick, older silicic volcanics, primarily rhyolites. This 5,000-foot depositional sequence typifies the subsurface geology of the 30-mile-wide Snake River Plain.

The sedimentary deposits of the area have been assigned to the Idaho Group of Miocene to Pleistocene Age. Figure E.2-4 presents a generalized stratigraphic column for the area and identifies the age, vertical distribution, and regional nomenclature of the formations comprising the Idaho Group. As a general rule, the deposits are unconsolidated except for some minor sandstone and limestone and the basaltic lava beds.

The sedimentary deposits of the Idaho Group were laid down under three distinct episodes of lava damming (and subsequent dam breaking) of the ancestral Snake River. These episodes resulted in the formation of large lakes across the region. Lacustrine (lake bed) deposits are frequently inter-tongued with fluvial (river) and flood plain deposits throughout the area, forming complex stratigraphic relationships on a regional scale. Generally, however, the lacustrine deposits predominate and form the most contiguous sedimentary beds across the Snake River Plain (Smith, Swirydczuk, Kimmel, and Wilkinson, 1982).

The basaltic formations that occur throughout the stratigraphic column were laid down as lava flows during active

AGE	FORMATION		
PLEISTOCENE	SNAKE RIVER BASALT		
	BRUNEAU FORMATION	IDAHO GROUP	
PLIOCENE	GLENN'S FERRY FORMATION		
MIOCENE	CHALK HILLS FORMATION		
	BANBURY BASALT		
	POISON CREEK FORMATION		
	IDAVADA VOLCANICS		

FIGURE E.2-4  
 STRATIGRAPHY OF THE WESTERN  
 SNAKE RIVER PLAIN  
 (MODIFIED AFTER MALDE AND POWERS, 1962)

periods of Miocene and Pleistocene volcanic activity. The basalt beds range in thickness from less than 10 feet to more than several hundred feet in the region. Other, minor beds of volcanic ash also are present in the stratigraphic sequence.

The several-hundred-foot-thick Snake River Basalt is the youngest formation in the regional sequence and forms a cap rock over the Idaho Group sediments throughout much of the regional area. In many areas of the Snake River Plain, the Snake River has eroded through the Snake River Basalt and into the underlying Idaho Group sediments. The Idaho Group sediments north of the river are capped by the resistant basalt, forming steep cliffs adjacent to the river. The Idaho Group sediments south of the river (and within the vicinity of Site B) generally lack the protective basalt cap and have been eroded, forming the badlands topography characteristic of the area.

#### E.2.4.2 STRUCTURE

The sedimentary and volcanic units of the Idaho Group tend to thicken toward the center of the Snake River Plain. The basin appears to be a graben (a downdrop fault-block) bounded by normal faults to the northeast and the southwest. Subsidence of the basin is apparently greatest in the center, thereby allowing greater accumulations of Idaho Group sediments near the center of the basin.

The regional dips of the Idaho Group units are gentle near the center of the basin, where they range from near horizontal to a maximum of about 10 degrees. The dips are generally to the northeast, with strike directions occurring to the northwest. Typically in the vicinity of Site B, regional dips of

2 to 4 degrees are reported, with strike directions approximately north 70 degrees west. Toward the margins of the basin, dips on the order of 10 degrees are reported.

Owing to the structural attitude (dip) of the Idaho Group strata, older units tend to be exposed at a considerable distance south of the Snake River, with younger units exposed progressively nearer the river. Faults are apparent throughout the region because of differential settlement of sedimentary beds and movements along the principal regional faults that border the Snake River Plain. Minor faults locally cut older units of the Idaho Group; the younger units, however, are generally unaffected since they were deposited after the faulting occurred. The faults typically parallel the plain; faulting transverse to the plain is not common.

#### E.2.5 LOCAL GEOLOGY

The local geology focuses on the characteristics of the Idaho Group sediments present in the vicinity of Site B. This information is presented as support for the site-scale findings and observations that are discussed later in this report.

In descending order, the localized formations are the Bruneau (100+ feet thick); the Glens Ferry (1,500+ feet thick); the Chalk Hills (200+ feet thick); the Banbury Basalt (200+ feet thick); and the Poison Creek (600+ feet thick). The Chalk Hills and Poison Creek Formations represent two individual lacustrine periods affecting the central and western portions, respectively, of the Snake River Plain. In some reports, particularly in many of the older geologic reports concerning the area and on numerous deep-drilling logs, the Poison Creek Formation is shown as occurring stratigraphically above the

Banbury Basalt. This is due to lithologic similarities between the Chalk Hills and Poison Creek Formations and the volcanism responsible for the deposition of Banbury Basalt into the lacustrine environments present.

The Bruneau and Glenss Ferry Formations are of prime interest to the site, since the Bruneau forms the uppermost geologic unit beneath Site B, and the Glenss Ferry is the unit where groundwater is first encountered. The deeper Banbury Basalt and Poison Creek Formations are also of importance, since these formations provide an area-wide source of deep flowing artesian groundwater, generally obtained from depths in excess of 2,000 to 3,000 feet. Because of the importance of the Bruneau and Glenss Ferry Formations to the Site B characterization, these units are discussed in detail below. Together, the units form a composite thickness of about 1,600 feet.

#### E.2.5.1 BRUNEAU FORMATION

The Pleistocene-Aged Bruneau Formation consists chiefly of unconsolidated lake deposits that contain basalt flows and tuff beds. In the vicinity of Site B, the formation is approximately 100 feet thick. The Bruneau is generally more coarse-grained than the underlying Glenss Ferry Formation and has been divided regionally into a basal gravel unit (approximately 40 feet thick), an overlying lower unit (approximately 70 feet thick), followed by an upper unit (approximately 20 feet thick). A 10- to 15-foot tuff layer separates the upper and lower units.

The basal gravel unit is composed of rounded pebbles, cobbles, and coarse-grained cross-bedded sand lenses. The origin of the unit is interpreted as a beach deposit of ancestral Lake Bruneau. Overlying the basal gravel is the lower unit, which

consists of a thin basaltic cinder bed, an intervening mottled clay, and a fine-grained tuffaceous sand. The upper unit of the Bruneau is lithologically similar to the lower unit, but regionally occurs above the 10- to 15-foot-thick tuff layer. Locally, the thicknesses and lithologic characteristics of the Bruneau units can vary considerably.

Minor recent and Pleistocene surficial deposits are also intermittently present in the local area and consist of Snake River terrace gravels, colluvium, and stream alluvium. The stream alluvium exists along the margins of permanent drainages, and the colluvium consists of random slope debris. These minor deposits are difficult to distinguish from the unconsolidated coarse-grained Bruneau Formation deposits on a local scale. For purposes of classification in this report, all surficial deposits in the vicinity of Site B are considered to be part of the Bruneau Formation, even though they may be of more recent geologic origin.

#### E.2.5.2 GLENNS FERRY FORMATION

The Glens Ferry Formation is of interest since the uppermost zone of saturation beneath Site B exists within this formation. The Glens Ferry is approximately 1,500 feet thick in the site area and is Pliocene to Pleistocene in age.

The Glens Ferry Formation was deposited in the area under three ancestral depositional environments. As a result, the three stratigraphic facies that are present differ from one another in lithologic composition and areal persistence. For classification purposes, the Glens Ferry has been divided into two units. The lower unit of the Glens Ferry Formation consists of a fluvial and lacustrine facies, while the upper unit consists of a flood plain facies. The lacustrine facies

is the most extensive and areally persistent sedimentary body in the Glens Ferry Formation.

Because of the structural dip of the beds in the Snake River Plain, all three facies are exposed at the land surface within the general area. The extensive lacustrine facies is exposed as a silt with minor clay, generally thick-bedded with thin stringers of very fine, tuffaceous sand. With depth, the lacustrine facies grades to a massive clay. At some exposures, the thick-bedded silt unit is overlain by several feet of very fine sand, alternately interbedded with additional silt. In many exposures, the fine sands are cross-bedded and show the presence of ripple marks. The sands generally denote the regional top of the lacustrine facies.

The less extensive fluvial facies overlies the lacustrine deposits, and generally consists of a fine- to medium-grained sand reaching a thickness of about 60 feet. Frequently, a one-inch-thick, tuffaceous, fine-grained sandstone is found at the top of the fluvial sand. Some cross-bedding is evident in the fluvial facies, and on a local scale the sand unit intertongues with the lacustrine facies.

The flood plain facies denotes the top of the Glens Ferry and consists of an interbedded sequence of clay, silt, and sand beds. Individual beds vary in thickness from about 2 to 4 feet in the general area and laterally persist for several hundred feet. At local exposures, the facies is about 200 feet thick. Plant fragments and other detritus are evident in the flood plain facies. Texturally, it appears banded (that is, possessing thin, laminae-like alternating beds) compared to the more homogeneous underlying lacustrine and overlying Bruneau Formation sediments.

### E.2.5.3 RELATIONSHIP OF LOCAL GEOLOGY TO SITE B

Detailed geologic mapping and subsurface data presented by Benfer (1984) indicate that complex sedimentary facies changes are to be expected in the vicinity of Site B. As a general rule, however, the lacustrine-derived deposits of the Glens Ferry Formation are the most continuous and persistent beds in the area since they are laid down in a somewhat sheetlike, areally extensive fashion. The fluvial- and flood plain-derived deposits would be expected to be more sporadic and discontinuous. The fine-grained extensive lacustrine silt and clay zones are therefore more areally persistent than the interbedded and discontinuous sandier zones of fluvial and flood plain origin.

The available published information suggests that much local variation exists in both the Bruneau and the Glens Ferry Formations, owing to the complex depositional history of the area. In general, however, as one transcends from the coarser-grained Bruneau Formation (locally found above the zone of saturation) to the underlying finer-grained Glens Ferry Formation (locally found below the zone of saturation), the sedimentary sequence becomes much more subtle, and clays and silts predominate. Distinct sedimentary units of the Glens Ferry are persistent across the site; however, within the individual units, considerable lateral variations have been noted.

In the published literature, there is no evidence of local faulting and other structural activity to suggest that bedding interruption by faulting exists. The sedimentary units exposed in the local area are generally not deformed. Older units of the Idaho Group show minor bedding movement in other areas of the Snake River Plain; however, in the immediate vicinity of Site B, where younger units of the Idaho Group

occur, such movement is not to be expected and has not been observed.

#### E.2.6 REGIONAL HYDROGEOLOGY

The groundwater resources of the area have been examined at the regional scale by several investigators. Mundorff, Crosthwaite, and Kilburn (1964) prepared a report on the occurrence of groundwater within the entire Snake River Plain. Ralston and Chapman (1969) investigated the groundwater resources of northern Owyhee County, and Young and Lewis (1982) examined the hydrology of deep thermal groundwater in southwestern Idaho. Several other groundwater availability and geothermal resource studies have been performed in the region, most notably by Brott, Blackwell, and Mitchell (1978) and Young, Lewis, and Bracken (1979). On the basis of these principal research studies, an overview of the groundwater resources of the region is presented below.

##### E.2.6.1 PRINCIPAL GROUNDWATER SYSTEMS

The regional studies indicate that two major groundwater systems are present in the area of Site B. These systems are:

1. An uppermost system found within the intermittent sand beds of the Glenns Ferry Formation. Groundwater is found at depths on the order of 140 to 350 feet in this system. In the published literature, this system is referred to as the shallow Glenns Ferry aquifer.
2. A deep system found most likely within the Banbury Basalt and the Poison Creek Formation. Groundwater is found at depths ranging from 600 to more

than 3,000 feet in this system. Water in this system is under considerable artesian pressure, and many wells tapping the aquifer are capable of flowing at the land surface. The deep (3,080 feet) artesian well drilled onsite for the U.S. Air Force in 1958 penetrates this aquifer and had a static pressure measured at the wellhead of 70 pounds per square inch. Water in this system is geothermally heated and serves as the primary groundwater resource in the area. In the published literature, this system is referred to as the deep artesian aquifer.

The most detailed investigation of the area is that of Ralston and Chapman (1969). In their study, the groundwater resources of approximately 2,300 square miles of northern Owyhee County were assessed. Their study area was segregated into eight hydrologic subareas, each possessing somewhat uniform hydrogeologic characteristics. Site B occurs within Ralston and Chapman's 130-square-mile Oreana hydrologic subunit, and the shallow Glens Ferry and deep artesian aquifers form the principal groundwater resources of the Oreana subunit. The following information on each of the two systems is derived from Ralston and Chapman's study.

#### E.2.6.1.1 Shallow Glens Ferry System

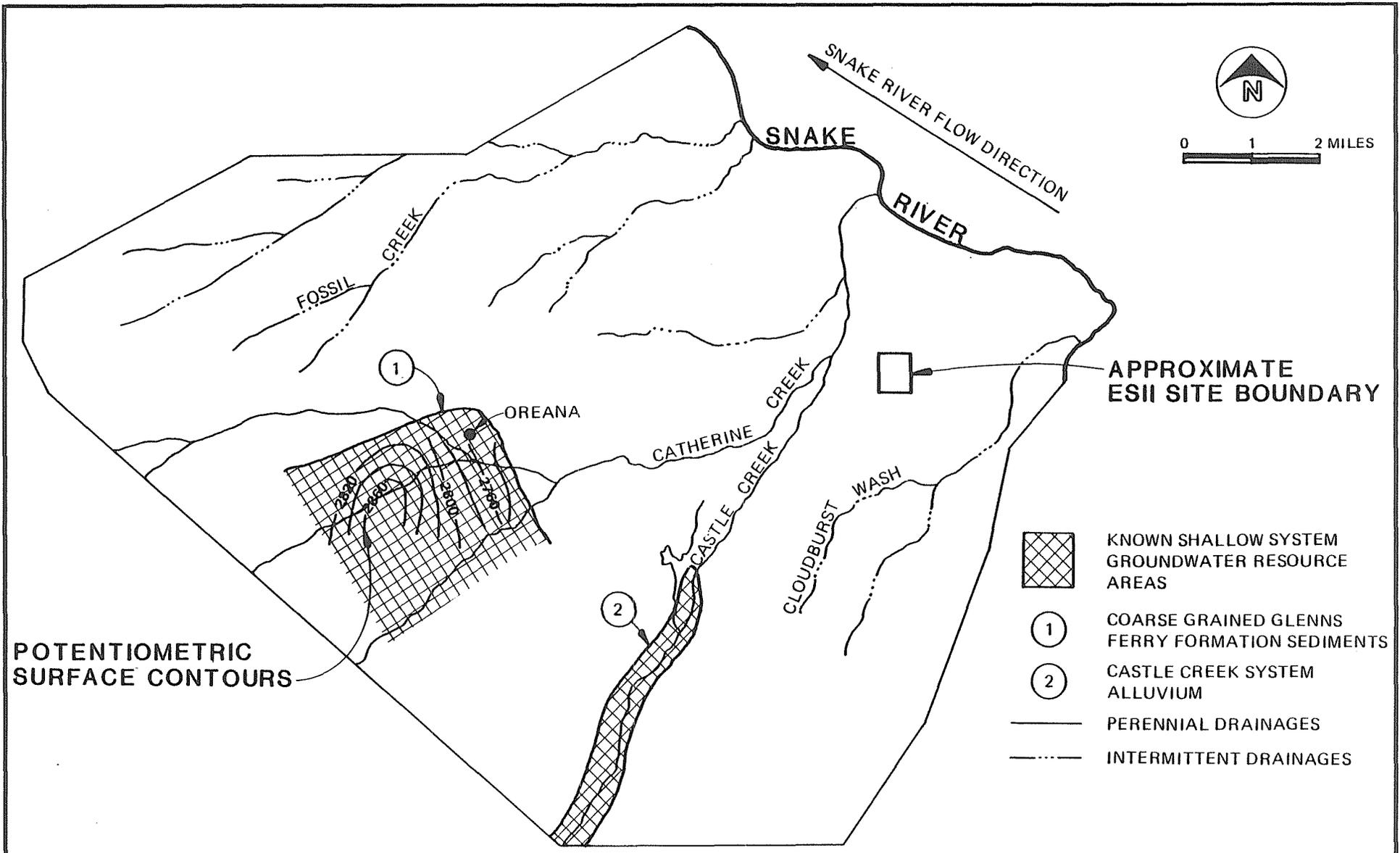
The shallow system found within the Glens Ferry Formation provides water to a number of irrigation and domestic wells in the immediate vicinity of the town of Oreana. This area is about 7 miles west of Site B.

The water is derived from a sequence of coarse-grained sediments found in the Glens Ferry at depths exceeding 200 feet. Ralston and Chapman mapped the lateral extent of

the coarser-grained sediments and observed that they occupy an area approximately 6 square miles in size. To the east of Oreana, at a distance of about one mile, the sediments grade laterally into finer-grained materials, and the ability of the system to provide usable quantities of water diminishes considerably. Although these finer-grained contiguous areas of the Glens Ferry Formation are saturated, Ralston and Chapman considered the 6-square-mile area as the only promising Glens Ferry zone within the Oreana subunit where usable quantities of shallow groundwater can be obtained. The yields of wells in this 6-square-mile area range from less than a few gallons per minute to over 1,900 gpm.

In addition to the 6-square-mile Glens Ferry groundwater resource area, a local veneer of saturated alluvium exists within the Oreana subunit along Castle Creek. The alluvium and the creek are reported to be hydraulically connected. Some shallow domestic wells have been installed in the alluvium, generally to depths not exceeding 50 feet. Most of this alluvial system development occurs approximately 8 miles southwest and upstream of Site B. As Castle Creek flows northeastward from this area to the Snake River, it passes to within 1-1/2 miles of Site B. It can reasonably be assumed that a veneer of saturated alluvium exists along Castle Creek in this downstream area as well.

Figure E.2-5 shows the locations of the shallow system groundwater resource areas mapped during Ralston and Chapman's study. Both the alluvial area and the 6-square-mile Glens Ferry groundwater resource area are shown. It can be seen that the location of Site B does not fall within either of these two identified shallow system groundwater resource areas, and both areas are hydraulically upgradient of the site.



SOURCE:  
RALSTON AND CHAPMAN (1969)

FIGURE E.2-5  
LOCATION OF SHALLOW SYSTEM GROUNDWATER  
RESOURCE AREAS WITHIN THE OREANA  
HYDROLOGIC SUBUNIT



Regional Flow Characteristics. Because of the remoteness and sparsely populated nature of the area, coupled with the limited and sporadic groundwater resource potential of the Glenns Ferry Formation, sufficient information was not available for Ralston and Chapman to make definitive regionalized findings in their study of shallow system flow directions and rates. Within the smaller 6-square-mile identified resource area, flow direction information is available, and the predominant direction of flow appears to be to the east. There is evidence of a localized groundwater divide within the 6-square-mile area, creating localized components of flow to the north and northwest. A limited potentiometric surface map was constructed by Ralston and Chapman for the 6-square-mile resource area. This is shown on Figure E.2-5.

The groundwater divide is evident from this limited potentiometric contour map, and it is possible that the divide has been caused by the influence of surface water infiltration from Catherine Creek, which, as shown on the figure, traverses directly through the center of the 6-square-mile groundwater resource area. Catherine Creek may therefore be a possible source of recharge to this system. Other principal drainages in the area, such as Castle Creek, may function in a similar capacity. Deep-seated artesian water moving up faults is recognized as a significant source of recharge to the shallow Glenns Ferry system in the area. Given the limited number of data points from which the potentiometric map was constructed, however, it is not possible to examine in detail the nature of surface water-groundwater interactions or structurally related recharge other than to suggest that they might occur.

No regional values of transmissivity, hydraulic conductivity, or storage coefficients are available for the area, and it

therefore is not possible to determine regional shallow system groundwater velocities or discharge rates. Again, because of the remoteness of the area and the apparently limited and sporadic shallow system groundwater resource potential, such aquifer evaluation tests have apparently not been conducted by public sector researchers.

#### E.2.6.1.2 Deep Artesian System

The deep artesian system is the primary source of groundwater in the Oreana hydrologic subunit. The system is areally extensive, forming a vast reservoir over much of southwestern Idaho. The system provides hot geothermal water (in excess of 100°F). As a general rule, considerable artesian pressure caused all wells completed in the system prior to 1960 to flow at the land surface when drilled. Water level declines in excess of 100 feet have been observed in the past 20 years, due to groundwater utilization in the area. Many of the existing wells no longer flow above ground, in response to the lowering of the potentiometric head to levels below the land surface. The locations at which flowing artesian water is encountered is therefore variable depending upon land surface elevation and proximity to areas where the potentiometric surface has undergone a decline.

The depths at which the deep artesian system is encountered is variable within the 130-square-mile Oreana subunit. In the northern portions of the area, well depths in excess of 2,500 feet are necessary. In the southern portions, hot artesian water is obtained at depths as shallow as 600 feet. Changes in surface topography are not sufficient by themselves to account for these differences. Ralston and Chapman (1969) have postulated that a series of northwest-trending faults near the base of the Owyhee Mountains may be operative in the southern portions of the Oreana subunit and are

providing avenues for the upward movement of artesian water. Such water may then be moving laterally from the faults within other higher elevation geologic formations. Former hot springs have been recorded in the historical literature within the general area of the faults, lending further support to this concept. The lowering of the potentiometric surface with time (as a result of groundwater resource development) may have eliminated the historical hot springs.

The formations that provide the hot artesian water are thought to be the Banbury Basalt and, to a lesser extent, the Poison Creek Formation. Hot artesian water may also be encountered within the Glens Ferry Formation to the south, as a result of the up-fault recharge concept from deeper zones. In general, however, most of the deep artesian wells in the area are completed in the Banbury Basalt.

Many of the older wells completed in the deep artesian system have been abandoned, yet continue to flow uncontrolled at the land surface. These uncontrolled wells contribute an appreciable flow to local drainages in the area and, in so doing, may provide additional surface recharge to the local alluvial and hydraulically contiguous shallow Glens Ferry system aquifer zones.

Regional Flow Characteristics. As with the shallow Glens Ferry system, the quantitative flow properties of the deep artesian system are largely unknown. Quantitative studies to determine the transmissivity, storage coefficient, and hydraulic conductivities of the system have not been performed via any public domain research studies. Therefore, it is not possible to quantify in detail actual groundwater velocities and discharge rates in the area.

Generalized information that is available indicates that the regional direction of flow of the deep artesian aquifer is

toward the Snake River, in a northerly fashion. This generalized finding is based upon water-level elevations observed by Ralston and Chapman (1969) in approximately 30 artesian wells scattered throughout the 130-square-mile Oreana subunit. Young and Lewis (1982) have also investigated the broad-scale flow patterns of the deep artesian system throughout southwestern Idaho and determined that in the local vicinity of Grand View and Oreana, flow in the system is predominantly to the northeast.

Recharge to the deep artesian system in the area is believed to originate in the Owyhee Mountains, where precipitation exceeds 50 inches annually. Groundwater moves from the mountains toward the Snake River, which has been proposed as a possible discharge point for at least a portion of the groundwater in the deep artesian system. The observed northeast direction of flow in this system is consistent with the generalized orientation of the landscape, the trend of regional surface water drainages, and the regional trend of the Owyhee Mountains relative to the position of the Snake River.

On a regional scale, hydraulic head in the deep artesian system is several hundred feet above the levels of head in the overlying shallow system. In addition to possible upward groundwater movement along faults (as discussed earlier), some upward movement to the shallow system probably occurs via leakage through overlying confining layers. The amount, however, is not known (Young and Lewis, 1982).

Relationship of the Deep Artesian System to Site B. An unused deep artesian well exists on the Site B property. At the time of publication of this report, the well is being abandoned and plugged with cement. Additional information on the nature of the regional flow system can be gained by a review of the characteristics of this well. The well was drilled to a depth of 3,080 feet and was completed in 1958

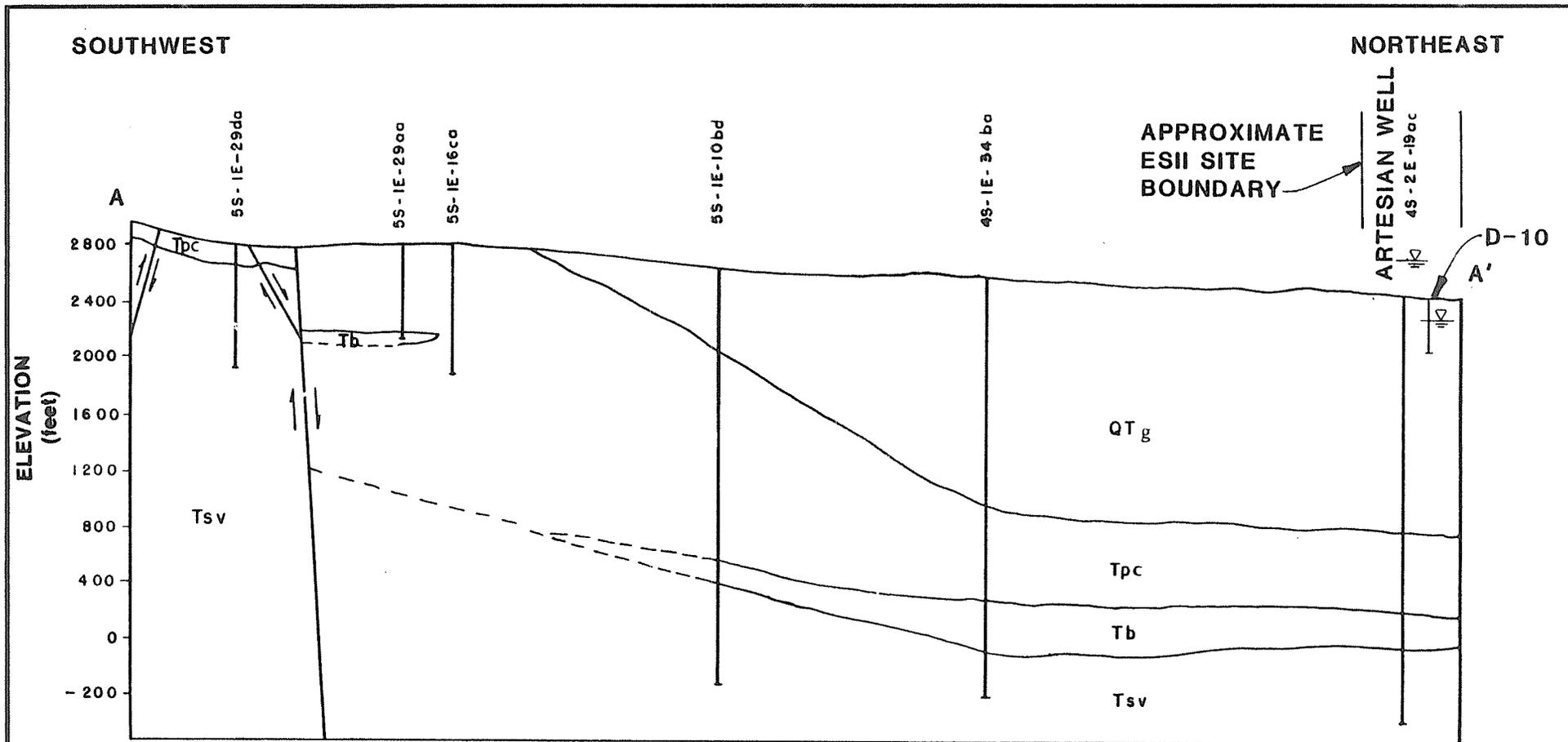
as a water source for the missile facility. The driller's log for this well, filed with the State Engineer's Office, is included in Appendix A.

Ralston and Chapman (1969) prepared a regionalized cross section of the Oreana hydrologic subunit and included the log of the Site B deep artesian well on the cross section. The cross section is reproduced as Figure E.2-6; the Site B deep artesian well is shown as Well 4S-2E-19ac. Figure E.2-7 shows the location of the cross section.

According to the driller's log and the regional cross section, the Glenns Ferry Formation underlies the site to a depth of 1,666 feet. The upper 173 feet of the formation was identified as coarse-grained, compared to the underlying interbedded clay and shale layers below 173 feet. The top of the Poison Creek Formation, beneath the Glenns Ferry, was identified by the presence of a consolidated cinder bed. Ralston and Chapman (1969) describe the Poison Creek Formation as a thick sequence of clay, silt, shale, volcanic ash, and sandstone. In the driller's log at Site B, it occurs as approximately 600 feet of alternating gray shale, clay, and cinder beds. In general, this formation is characterized by a low yield of warm artesian water.

At a depth of 2,291 feet, the Banbury Basalt was penetrated and occurs as approximately 225 feet of alternating black basalt and gray shale. It is an important source of hot artesian water in the area. Underlying the Banbury Basalt are the Tertiary silicic volcanics identified as alternating rhyolite and gray shale grading into black and red sands and sandstones. The silicic volcanics are considered the basement rocks of the Snake River Plain.

The deep artesian well at Site B is cased to a depth of 2,515 feet and is open-hole from 2,515 to 3,080 feet.



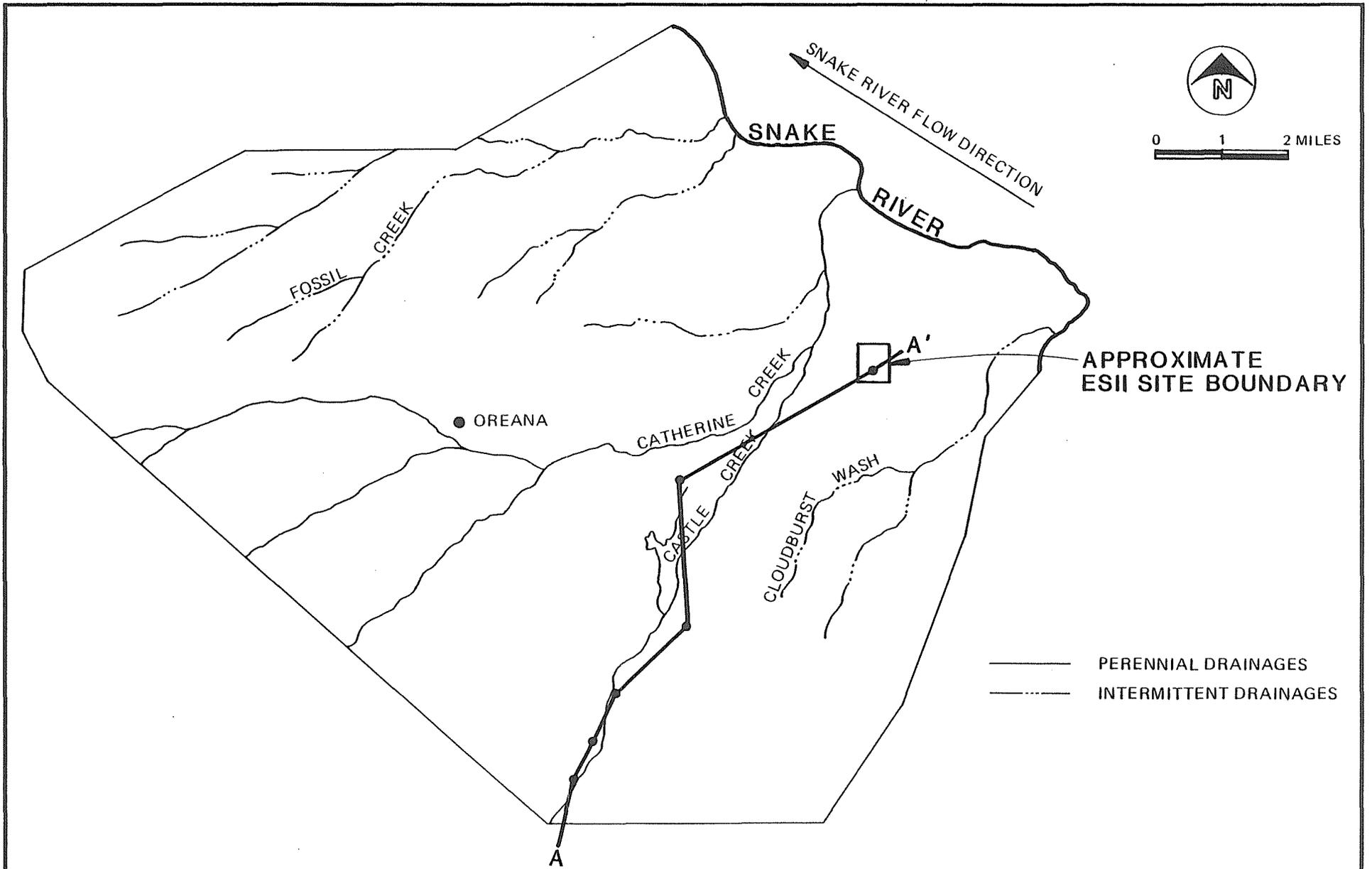
0 1 2 MILES

LEGEND

- Qtg Glenns Ferry Formation
- Tpc Poison Creek Formation
- Tb Banbury Basalt
- Tsv Tertiary Silicic Volcanics
- ▽ Potentiometric Head Level

FIGURE E.2-6  
HYDROGEOLOGIC CROSS SECTION A-A'  
(MODIFIED AFTER RALSTON AND CHAPMAN, 1969)





SOURCE:  
RALSTON AND CHAPMAN (1969)  
OREANA HYDROLOGIC SUBUNIT

B18066.C0

FIGURE E.2-7  
LOCATION MAP FOR  
HYDROGEOLOGIC CROSS  
SECTION A-A'



*Circle*  
*Revised to Shannon Wilson #15*  
Anderson and Kelly (1980) note the following occurrences of water in the deep well:

- o Artesian water found at a depth of 2,400 feet
- o 50 gpm at a depth of 3,000 feet
- o 335 gpm at the bottom of the well

This information suggests that the source of the artesian water is probably the lower Banbury Basalt and the silicic volcanics, consistent with the regionalized findings of Ralston and Chapman (1969).

*Circle*  
Referring again to Figure E.2-6, a recently installed Site B piezometer (identified as Number D-10) is shown in vertical perspective to the deep artesian well. Recent pressure head tests conducted on the artesian well indicate a value of 70 psi at the well-head. This value represents a head of 161 feet above the land surface. This head level is approximately 335 feet above the heads observed at D-10, as shown on Figure E.2-6. A considerable upward hydraulic gradient therefore exists between the deep artesian system and the shallow Glenss Ferry system immediately beneath Site B. Hence, it is not possible for waste constituents from the site to migrate downward to the deep artesian aquifer.

The driller's log of the artesian well identified no major aquifer zones between the shallow Glenss Ferry system and the deep artesian zone, spanning an interval of several thousand feet. Therefore, the uppermost water-bearing zones currently being monitored within the Glenss Ferry Formation are of primary interest in this report.

*Circle*  
BOT513/003

*add 4 on  
literature search  
more records  
draft 2*

### E.3 INVESTIGATIVE METHODS

Hydrogeologic investigations at the ESII site were conducted to meet the objectives established in Section E.1.2. The investigations obtained the data necessary to describe the hydrogeologic framework and to identify and characterize the uppermost aquifer underlying the site. This section describes the scope and methods used in the investigations at the site.

The first subsurface geologic investigation of the site was conducted in 1958, before the missile base was built, by Shannon and Wilson for the U.S. Air Force. Most of the drilling conducted during this preconstruction period focused on shallow (less than 150 feet) conditions. Hollow stem auger and fluid rotary drilling techniques were used. Although four of the 10 Shannon and Wilson borings were extended to 200 feet, no groundwater was reported.

In 1981 and 1982, Northern Testing and Engineering drilled seven shallow geotechnical borings, 17 to 152 feet deep, using hollow stem augers. The purpose of these holes was to identify the shallow stratigraphy and obtain geotechnical foundation information. Additional shallow (41 to 140 feet) geotechnical information was obtained by hollow stem auger borings drilled by CH2M HILL in September and October 1983.

These shallow geotechnical borings and the four deep Shannon and Wilson borings provided the data base for the subsurface geology and groundwater conditions at the site prior to the first deep test boring installed by CH2M HILL in September 1983. Groundwater was first reported in Boring D-2, which was drilled by CH2M HILL in 1983 in the northeast corner of the site. The original purpose of this boring was to provide

additional information for preparation of a groundwater monitoring waiver demonstration since groundwater had not been reported above 1,600 feet at this site. However, following the discovery of groundwater at 183 feet, numerous borings, test wells, and monitoring wells were installed to characterize the hydrogeology of the site. A total of 78 test borings, test wells, and monitoring wells have been drilled at and around Site B, beginning with Shannon and Wilson's work. Table E.3-1 provides the coordinate location, dates drilled, depths, and current disposition of all wells and borings drilled in the study area. Figure E.3-1 shows the well and boring locations.

Investigative methods used on this site include standard field and laboratory procedures, and new drilling techniques that were developed for this project in response to formation and depth limitations of the conventional methods. Drilling, well completion and development, sampling, and testing techniques used to obtain hydrogeologic data on the site are described in the following sections.

#### E.3.1 DRILLING METHODS

Some borings and wells were constructed using several different techniques. The purpose of the hole dictated the method of construction. Table E.3-1 provides information on the drilling method used over specific depth intervals for each boring and well. The methods are described below.

Hollow Stem Augers. Conventional 7-1/4-inch OD (outside diameter), 3-1/2-inch ID (inside diameter) hollow stem augers have been used for shallow, unconsolidated soils sampling and geotechnical testing. Drill rig power and auger strength typically limit to less than 150 feet the depth to which

*Check  
 all D logs, D73M  
 D75  
 SW1-2*

Table E.3-1  
 BOREHOLE INVENTORY

Boring Number	Date(s) Drilled	North Coordinate	East Coordinate	Depth(s) Drilled (ft)	Drilling Method(s)	Engineer	Status
M2-A1	8/27/58-8/29/58	6,840	6,020	0-200.0	Coring	S&W	Plugged?
M2-B1	8/23/58, 8/25/58-8/27/58	6,520	5,575	0-200.0	Coring	S&W	Plugged?
M2-B	12/17/58-12/19/58, 1/1/59-1/9/59	6,825	5,940	0-200.0	Coring	S&W	Plugged?
M2-C1	8/26/58	6,530	6,025	0-50.0	Coring	S&W	Plugged?
M2-D1	8/28/58-8/30/58, 9/1/58	6,545	6,475	0-200.0	Coring	S&W	Plugged?
M2-E1	8/23/58, 8/25/58	6,380	5,730	0-50.0	Coring	S&W	Plugged?
M2-F1	8/20/58-8/22/58	6,380	6,320	0-50.0	Coring	S&W	Plugged?
M2-H1	8/20/58-8/22/58	5,575	6,040	0-50.0	Coring	S&W	Plugged?
M2-J	1/3/59, 1/7/59-1/9/59	6,160	6,020	0-140.0	Coring	S&W	Plugged?
M2-L	12/19/58-12/20/58, 1/2/59, 1/3/59	5,755	6,190	0-60.0	Coring	S&W	Plugged?
DH-1	10/8/81-10/12/81	7,380	6,050	0-120.0	HSA	NT&EN	Plugged with bentonite top to bottom 10/19/81-10/21/81
DH-2	10/12/81	7,620	5,055	0-40.0	HSA	NT&EN	Plugged with drill cuttings
DH-3	10/13/81-10/22/81	5,005	6,970	0-131.4	HSA	NT&EN	Plugged with bentonite top to bottom 10/22/81-10/26/81
DH-4	10/22/81-10/23/81	5,110	6,970	0-60.0	HSA	NT&EN	Plugged with drill cuttings
DH-5	10/23/81-10/28/81	5,005	6,840	0-49.5	HSA	NT&EN	Plugged with drill cuttings

Table E.3-1 (Continued)  
BOREHOLE INVENTORY

<u>Boring Number</u>	<u>Date(s) Drilled</u>	<u>North Coordinate</u>	<u>East Coordinate</u>	<u>Depth(s) Drilled (ft)</u>	<u>Drilling Method(s)</u>	<u>Engineer</u>	<u>Status</u>
DH-6	10/27/81-10/29/81	5,020	5,010	0-152.1	HSA	NT&EN	Plugged with bentonite top to bottom, 10/30/81
DH-7	11/16/82	6,685	5,640	0-17.0	HSA	NT&EN	Plugged with drill cuttings
DH-8	11/16/82	6,625	5,560	0-21.5	HSA	NT&EN	Plugged with drill cuttings
DH-9	11/16/82	6,570	5,580	0-22.0	HSA	NT&EN	Plugged with drill cuttings
B-1	9/19/83-9/20/83	6,680	5,075	0-126.3	HSA	CH2M	Plugged with 47 bags Portland cement, 9/21/83
B-2	10/4/83	5,950	5,390	0-121.5	HSA	CH2M	Plugged, grouted
B-3	9/7/83	5,320	5,260	0-105.0	HSA	CH2M	Plugged with 45 bags Portland cement
B-4	9/10/83-9/12/83	5,310	6,440	0-109.67	HSA	CH2M	Plugged with 46 bags Portland cement, 9/12/83
B-5	9/16/83	5,870	6,580	0-41.5	HSA	CH2M	Plugged with 15 bags Portland cement, 9/16/83
B-6	9/21/83-9/23/83 9/23/85 9/24/83	6,220	6,770	0-107.0 107.0-122.0 122.0-139.8	HSA WRB WRC	CH2M CH2M CH2M	Plugged with 21 bags Portland cement, 9/26/83
B-7	9/16/83-9/17/83	7,040	6,880	0-61.4	HSA	CH2M	Plugged with 17 bags Portland cement, 9/17/83
D-1	10/1/83-10/3/83 10/3/83-10/19/83	5,120	5,925	0-105.5 105.5-237.9	HSA AR	CH2M	Plugged with 135 bags Portland cement

Table E.3-1 (Continued)  
BOREHOLE INVENTORY

Boring Number	Date(s) Drilled	North Coordinate	East Coordinate	Depth(s) Drilled (ft)	Drilling Method(s)	Engineer	Status
D-2	9/8/83-9/9/83 9/10/83 9/10/83-9/22/83 9/22/83-10/1/83	7,625	6,350	0-30.0 30.0-75.0 75.0-285.0 285.0-430.0	AR HSA AR WRC	CH2M CH2M CH2M CH2M	Plugged with 150 bags Portland cement 10/11/83-10/20/83
D-3	10/11/83-10/12/83 4/11/84-4/19/84	5,096.5	6,059.8	0-303.0 303.0-407.0	AR WRC	CH2M CH2M	2-level piezometer
D-4	10/12/83-10/14/83 5/9/84-5/14/84	7,598.5	5,133.4	0-254.0 254.0-400.0 254.0-400.0	AR WRC AR	CH2M CH2M CH2M	2-level piezometer  Drilled out to 8"
D-8	5/11/84-5/15/84 5/17/84-5/21/84	6,439.1	6,073.1	0-195.0 195.0-400.0	AR WRC	CH2M CH2M	2-level piezometer
D-9	5/16/84 5/22/84-5/29/84	6,153.7	6,936.4	0-195.0 195.0-401.5	AR WRC	CH2M CH2M	2-level piezometer
D-10	5/16/84-5/17/84 5/31/84-6/2/84	7,622.2	6,830.8	0-190.0 190.0-401.5	AR WRC	CH2M CH2M	2-level piezometer
D-16	10/22/84-10/23/84 11/20/84 11/29/84-12/3/84	7,089.5	5,373.0	0-100.0 100.0-125.0 125.0-301.0	AR WRC WRC	CH2M CH2M CH2M	Hole collapsed, plugged
D-16A	1/24/85-2/4/85	7,181.69	5,373.87	0-260.0	AR	CH2M	Replacement for D-16 test well; plugged 10/85
D-17	10/29/84-10/30/84	5,577.3	6,212.1	0-300.0	AR	CH2M	Test well
D-18	10/30/84-11/5/84	7,565.9	5,548.8	0-260.0	AR	CH2M	Test well
D-19	1/9/85-1/15/85	7,135.81	6,670.85	0-250.0	AR	CH2M	Test well
D-20	1/10/85-1/21/85	7,097.56	6,673.98	0-390.0	AR	CH2M	Test well
D-22	3/27/85-3/28/85 3/28/85-4/2/85	5,782.20	6,890.02	0-110.0 110.0-300.0	HSA WRC	CH2M CH2M	Hole plugged and plate welded on top 4/10/85

Table E.3-1 (Continued)  
BOREHOLE INVENTORY

Boring Number	Date(s) Drilled	North Coordinate	East Coordinate	Depth(s) Drilled (ft)	Drilling Method(s)	Engineer	Status
D-23	4/11/85 4/12/85-4/17/85	6,976.01	5,039.19	0-110.0 110.0-315.0	HSA WRC	CH2M CH2M	Piezometer
D-27	9/17/85-9/19/85	5,007.70	5,438.95	0-300.0	AR	CH2M	Test well
D-28	9/20/85-9/24/85	5,009.65	6,257.03	0-300.0	AR	CH2M	Test well
D-29	9/25/85-9/27/85	5,011.29	6,816.29	0-300.0	AR	CH2M	Test well
D-30	9/30/85-10/2/85	5,065.50	5,012.11	0-300.0	AR	CH2M	Test well
D-31	10/3/85-10/7/85	5,574.87	5,727.33	0-253.0	AR	CH2M	Test well
D-32	10/2/85-10/4/85	5,492.79	5,718.27	0-299.0	WRC	CH2M	Core hole plugged 10/6/85; cemented top to bottom with 20 bags of cement
<del>D-33</del> 2-34							
MW-1	12/8/83-12/9/83	7,631.5	6,320.1	0-235.0	AR	CH2M	Monitoring well
MW-2 (D-5)	10/17/83-10/18/83	7,635.2	6,817.0	0-300.0	AR	CH2M	Boring D-5 converted to monitoring well
MW-3	12/2/83-12/3/83	6,992.0	6,961.7	0-240.0	AR	CH2M	Monitoring well
MW-4 (D-7)	10/25/83-10/26/83	6,125.4	6,969.6	0-280.0	AR	CH2M	Boring D-7 converted to monitoring well
MW-5	11/28/83-11/29/83	5,345.3	6,951.4	0-250.0	AR	CH2M	Monitoring well
MW-6 (D-6)	10/20/83-10/21/83	5,653.1	5,059.1	0-280.0	AR	CH2M	Boring D-6 converted to monitoring well
MW-7	3/30/84-4/2/84	7,569.3	5,453.9	0-260.0	AR	CH2M	To be plugged
MW-8	3/30/84-4/3/84	7,559.2	5,769.1	0-260.0	AR	CH2M	To be plugged
MW-8A	4/19/84-4/20/84	7,558.1	5,750.6	0-165.0	AR	CH2M	To be plugged

Table E.3-1 (Continued)  
BOREHOLE INVENTORY

<u>Boring Number</u>	<u>Date(s) Drilled</u>	<u>North Coordinate</u>	<u>East Coordinate</u>	<u>Depth(s) Drilled (ft)</u>	<u>Drilling Method(s)</u>	<u>Engineer</u>	<u>Status</u>
MW-9	4/17/84-4/18/84	7,572.5	6,584.3	0-260.0	AR	CH2M	Test well converted to monitoring well
MW-10	4/5/84-4/16/84	7,324.1	6,901.9	0-250.0	AR	CH2M	Test well converted to monitoring well
MW-11	3/29/84-3/30/84	6,629.9	6,900.2	0-265.0	AR	CH2M	Test well converted to monitoring well
MW-12	3/29/84-3/30/84	5,729.5	6,887.9	0-265.0	AR	CH2M	Test well converted to monitoring well
MW-13	10/1/84-10/3/84	4,790.4	4,507.1	0-300.0	AR	CH2M	Test well converted to monitoring well
MW-14	10/3/84-10/5/84	5,622.0	4,561.7	0-290.0	AR	CH2M	Test well
MW-15 (D-15)	10/8/84-10/9/84	7,202.0	5,056.5	0-270.0	AR	CH2M	Test well D-15 converted to monitoring well MW-15
MW-16	8/15/85-8/19/85	6,747.58	4,889.10	0-200.0	AR	CH2M	Monitoring well
MW-21 (D-21)	3/16/85-3/17/85 3/18/85-3/22/85	6,762.88	6,926.71	0-108.5 108.5-300.0	HSA WRC	CH2M CH2M	Test well D-21 converted to monitoring well MW-21
MW-24 (D-24)	4/12/85-4/18/85	6,261.74	6,944.06	0-280.0	AR	CH2M	Test well D-24 converted to monitoring well MW-24
MW-25	8/22/85-8/26/85	7,386.04	6,918.90	0-290.0	AR	CH2M	Monitoring well
MW-26	8/14/85-8/21/85	7,568.66	6,342.49	0-290.0	AR	CH2M	Monitoring well
PCB-1	6/19/85-7/5/85	6,442.81	5,373.16	0-197.0	AR	CH2M	Monitoring well
PCB-2	7/9/85-7/18/85	6,627.80	5,372.06	0-200.5	AR	CH2M	Monitoring well
PCB-3	7/19/85-8/3/85	7,133.75	5,372.59	0-195.0	AR	CH2M	Monitoring well
SW-1	7/25/84-10/24/84	6,448.7	5,674.0	0-220.0	MCT	CH2M	Monitoring well

Table E.3-1 (Continued)  
BOREHOLE INVENTORY

<u>Boring Number</u>	<u>Date(s) Drilled</u>	<u>North Coordinate</u>	<u>East Coordinate</u>	<u>Depth(s) Drilled (ft)</u>	<u>Drilling Method(s)</u>	<u>Engineer</u>	<u>Status</u>
SW-2	2/21/85 2/22/85-3/18/85	6,821.60	5,861.98	0-20.0 20.0-204.0	AR MBA	CH2M CH2M	Monitoring well
SW-3	4/22/85-5/22/85	6,670.56	6,117.75	0-20.0 20.0-202.5	AR MBA	CH2M CH2M	Monitoring well
WW-1 (Water Well)	10/3/84-10/26/84	5,636.4	4,537.6	0-800.0	AR	CH2M	Plugged with bentonite slurry; plate welded on top

Drilling Methods:

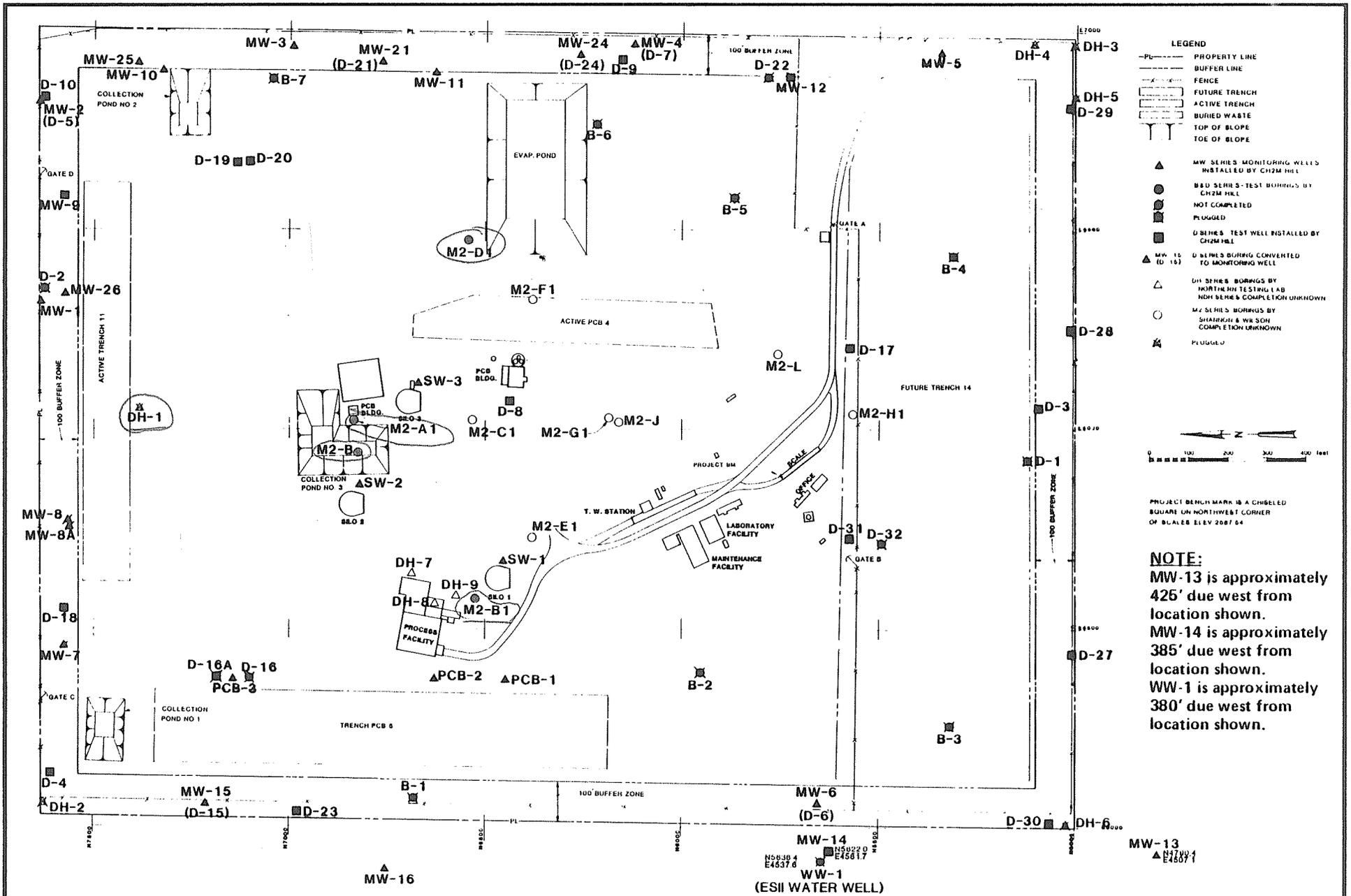
AR Air Rotary  
HSA Hollow Stem Auger  
WRC Wash Rotary Core  
MCT Modified Cable Tool  
MBA Modified Bucket Auger  
WRB Wash Rotary Rock-Bit

Abbreviations and Remarks:

CH2M CH2M HILL  
S&W Shannon & Wilson  
NT&EN Northern Testing & Engineering  
( ) Denotes D-Series Converted to Monitoring Well

BOT420/050

*all SW-1-2  
SW-3-2*



**FIGURE E.3-1  
 WELL AND BORING  
 LOCATIONS**



*add SW 3.2, 1.2, D-33, D 29*

hollow stem augers can be used. The deepest hollow stem auger hole at this site was Boring DH-6 (152 feet).

D-34 (155)

Hollow stem augers permit sampling of unconsolidated soils without pulling the augers out of the hole, which may result in the hole collapsing. In some of the holes installed during this investigation, hollow stem augers were used to advance the hole to a depth where formation characteristics were suitable for coring, typically at 110 feet.

Add it on  
Continuous  
Sampling

Air Rotary. Most of the monitoring and test wells installed during this investigation were drilled using air rotary drilling methods. Foam and water injection was used to aid in cuttings removal for all air rotary wells installed before Well PCB-3. The foaming agent, "Quick Foam," is a nontoxic concentrated soap approved for use in potable water wells. A sample of the foam was collected for chemical analysis if organic compounds were detected in the initial samples from the wells. The same foam was used on all wells.

To obtain better geologic logs from the drill cuttings (including moisture variations in the geologic section and positive identification of the top of the first water-saturated strata) dry air rotary techniques were used on Well PCB-3, and on all "D" and "MW" wells installed after PCB-3. To clear the well of cuttings without using water injection and a foaming agent, it was necessary to use a booster air compressor providing 600 cfm at 250 psi. The second compressor was connected to the drill rig and augmented the rig's compressor. Once the first saturated sands were encountered, it was necessary to use water and foam injection to clear the cuttings from the hole.

Most of the air rotary holes were drilled with a 7-7/8-inch tricone roller bit. Steel surface casing (8-inch ID) was driven downward as the hole was advanced. Wells MW-2, MW-4,

and MW-6 were drilled with a 5-7/8-inch tricone roller bit, and a 6-inch ID steel casing was driven. For all air rotary-drilled wells, the steel casing was seated in clayey strata 120 to 160 feet below ground level. The annulus outside of the steel casing was filled with dry granulated bentonite as the casing was driven. The open hole was drilled from the bottom of the casing to the total depth of the well borehole. The final well screen and casing were installed in the open hole and extended up through the steel casing to the surface.

Rotary Coring. Several test borings were advanced by continuous coring techniques. An NQ wireline retrievable core barrel 2-7/8 inches OD was used. Holes D-21, D-22, D-23, and D-32 were cored through hollow stem augers drilled to about 110 feet, where the upper geologic section becomes more clay rich and is consolidated enough to recover cores. Split spoon samples (described below) were taken on 5-foot intervals from the surface to the depth of the augers.

Some of the initial deep borings installed by CH2M HILL, D-1 through D-10, were drilled by a combination of air rotary and NQ wireline cores. Table E.3-1 indicates the drilling methods and intervals used.

Special Drilling Methods. In response to safety concerns and soil sample integrity, special drilling methodology and equipment were developed for the Agreed Order silo investigation. This method allowed the holes to be advanced by repeatedly removing a "plug" of the formation one to 3 feet long. No fluid or air was introduced into the hole. Cable tool and rotary adaptations were tried, and the rotary method proved much faster and provided better sample recovery. The cable tool method consisted of driving a 5-foot section of 7-1/4-inch OD steel casing fitted with a hardened drive shoe. The bit was driven into the soil with the downhole hammer

and churning action of the cable tool rig. The rotary adaptation required advancing the hole with a 7-1/4-inch OD hollow auger bit. The bit was turned and pushed into the soil until refusal, which was typically 2 to 3 feet. ~~A sawtoothed auger bit resulted in a faster drilling rate with the rotary rig.~~ Temporary 8-inch OD steel casing, to provide hole stability, was driven as the borehole was advanced. The 8-inch casing was retracted as the primary well casing and annular seals were placed.

### E.3.2 WELL CONSTRUCTION

Most of the test borings drilled under the supervision of CH2M HILL were completed as test wells or monitoring wells. Well construction has varied somewhat, but most wells consist of 4-inch ID, Schedule 40 PVC joined with threaded flush joints and 4-inch ID PVC slotted well screens. Screen slots are .010 inch (except SW-1, which has a slot size of .020 inch), and 16-mesh, clean silica sand was used for a filter pack around the screens. The silo wells have 4-inch ID stainless steel screens and steel well casings. Five of the borings were completed as dual-level, small-diameter piezometers. The piezometers were constructed with 3/4-inch ID, Schedule 80 PVC well casings and screens. Table E.3-2 shows the construction details for wells and piezometers installed at the site.

The primary PVC well casing was installed through the outer steel casing. In most wells the steel surface casing extended down from 120 to 160 feet and was left in place. On the silo test wells, the surface casing was retracted as the primary well casing, screen, sand pack, and annular seals were placed. The annulus between the borehole and well casing and the well casing and the steel surface casing were sealed with dry bentonite or bentonite and cement grout. The top 10 feet of the annulus between the PVC and the steel

Table E.3-2  
WELL CONSTRUCTION SUMMARY

Well No.	GL Elev. (ft MSL)	Top of Casing Elev. (ft MSL)	Total Depth Drilled (ft)	Steel Surface Casing Depth (ft BGL) <sup>a</sup>	Well Casing					Open Interval				Dedicated <sup>g</sup> Sampling Equipment	
					Diam. (in)	Type <sup>b</sup>	Depth (ft BGL)	SC/OH <sup>c</sup>	Diam. (in)	Type <sup>b</sup>	Screen Interval (ft)	Slot Size (in)	Sand Pack Interval (ft)		Static <sup>d</sup> Water Level (ft BGL)
MW-1	2558	2559.57	235	138	4	PVC	214	SC	4	PVC	174-194	.010	154-216	180	SP
MW-2	2558	2559.97	300	158	3	PVC	231	SC	3	PVC	191-211	.010	166-291	193	PB
MW-3	2548	2549.95	240	118	4	PVC	219	SC	4	PVC	179-199	.010	154-232	185	SP
MW-4	2559	2560.02	280	139	3	PVC	235	SC	3	PVC	195-215	.010	167-255	200	PB
MW-5	2568	2569.56	250	118	4	PVC	232	SC	4	PVC	200-220	.010	176-237	205	SP
MW-6	2597	2598.10	280	119	3	PVC	230	SC	3	PVC	190-210	.010	160-256	196	PB
MW-7	2560	2562.70	260	137	8	-	-	OH	-	-	-	-	Sloughed		
MW-8	2565	2566.59	260	158	8	ST	218	OH	6	-	-	-	Sloughed		
MW-8A	2563	2566.59	165	117	8	-	-	OH	-	-	-	-	Sloughed		
MW-9	2565	2565.27	260	139	4	PVC	250	SC	4	PVC	190-230	.010	174-250	196	
MW-10	2539	2541.51	250	117	4	PVC	225	SC	4	PVC	175-215	.010	160-230	175	SP
MW-11	2555	2556.85	265	118	4	PVC	240	SC	4	PVC	190-230	.010	178-247	192	SP
MW-12	2563	2565.30	265	118	4	PVC	250	SC	4	PVC	200-240	.010	189-250	202	
MW-13	2632	2633.72	300	158	4	PVC	265	SC	4	PVC	215-255	.010	193-265	189	SP
MW-14	2606	2606.92	290	159	4	PVC	235	SC	4	PVC	210-230	.010	205-235	187	
MW-15	2545	2547.24	270	158	4	PVC	220	SC	4	PVC	170-210	.010	160-250	157	SP
MW-16	2566	2568.15	200	118	4	PVC	195	SC	4	PVC	180-190	.010	178-196	183	SP
MW-21	2552	2555.17	300	118	4	PVC	265	SC	4	PVC	255-265	.010	245-262	192	SP
MW-24	2557	2559.52	280	118	4	PVC	274	SC	4	PVC	245-255	.010	236-274	198	SP
MW-25	2542	2543.56	290	118	4	PVC	278	SC	4	PVC	263-273	.010	255-283	185	SP
MW-26	2567	2569.49	290	157	4	PVC	277	SC	4	PVC	262-272	.010	255-280	199	SP
D-3s <sup>e</sup>	2603	2605.54	407	97	3/4	PVC	225	SC	3/4	PVC	195-215	.010	176-230	209	
D-3d <sup>e</sup>	2603	2605.52	407	98	3/4	PVC	315	SC	3/4	PVC	285-305	.010	273-308	213	

Table E.3-2 (continued)  
WELL CONSTRUCTION SUMMARY

Well No.	GL Elev. (ft MSL)	Top of Casing Elev. (ft MSL)	Total Depth Drilled (ft)	Steel Surface Casing Depth (ft BGL) <sup>a</sup>	Well Casing						Open Interval				Dedicated <sup>g</sup> Sampling Equipment
					Diam. (in)	Type <sup>b</sup>	Depth (ft BGL)	SC/OH <sup>c</sup>	Diam. (in)	Type <sup>b</sup>	Screen Interval (ft)	Slot Size (in)	Sand Pack Interval (ft)	Static <sup>d</sup> Water Level (ft BGL)	
D-4s <sup>e</sup>	2528	2530.09	400	118	3/4	PVC	215	SC	3/4	PVC	185-205	.010	175-215	140	
D-4d <sup>e</sup>	2528	2530.06	400	118	3/4	PVC	300	SC	3/4	PVC	270-290	.010	260-300	143	
D-8s <sup>e</sup>	2566	2568.66	400	138	3/4	PVC	240	SC	3/4	PVC	210-230	.010	200.5-240	191	
D-8d <sup>e</sup>	2566	2568.65	400	138	3/4	PVC	320	SC	3/4	PVC	290-310	.010	280-315	190	
D-9s <sup>e</sup>	2559	2561.18	401.5	118	3/4	PVC	230	SC	3/4	PVC	185-205	.010	189-231	197	
D-9d <sup>e</sup>	2559	2561.22	401.5	118	3/4	PVC	320	SC	3/4	PVC	290-310	.010	280-321	198	
D-10s <sup>e</sup>	2556	2558.34	401.5	138	3/4	PVC	230	SC	3/4	PVC	200-220	.010	190-230	191	
D-10d <sup>e</sup>	2556	2558.34	401.5	138	3/4	PVC	310	SC	3/4	PVC	280-300	.010	270-310	196	
D-16	2561	-	300	100	-	-	-	-	-	-	Plugged	-	-	-	
D-16A	2561	2562.95	260	118	-	-	-	-	-	-	Plugged	-	-	-	
D-17	2585	2586.84	300	118	4	PVC	250	SC	4	PVC	190-230	.010	180-290	209	
D-18	2563	2564.61	260	138	4	PVC	215	SC	4	PVC	165-205	.010	160-260	175	
D-19	2558	2560.14	250	118	4	PVC	240	SC	4	PVC	190-230	.010	180-250	192	
D-20	2558	2560.53	390	137	4	PVC	360	SC	4	PVC	310-350	.010	293-360	196	
D-21s <sup>f</sup>	2552	2555.17	300	118	3/4	PVC	220	SC	3/4	PVC	205-215	.010	189-220	192	
D-22	2563	-	300	-	-	-	-	-	-	-	Plugged	-	-	-	
D-23	2552	2552.93	315	4	3/4	PVC	177	SC	3/4	PVC	167-177	.010	165-177	165	
D-24s <sup>f</sup>	2557	2559.52	280	118	3/4	PVC	192	SC	3/4	PVC	175-185	.010	163-192	Dry	
D-27	2613	2614.27	300	99	4	PVC	237	SC	4	PVC	222-232	.010	218-247	205	
D-28	2603	2604.76	300	98	4	PVC	239	SC	4	PVC	224-234	.010	219-249	221	
D-29	2579	2580.51	300	97	4	PVC	227	SC	4	PVC	212-222	.010	207-238	210	
D-30	2613	2615.07	300	98	4	PVC	223	SC	4	PVC	208-218	.010	203-233	194	
D-31	2594	2596.38	253	98	4	PVC	248	SC	4	PVC	233-243	.010	228-253	210	
D-32	2596	-	299	-	-	-	-	-	-	-	Plugged	-	-	-	

Table E.3-2 (continued)  
WELL CONSTRUCTION SUMMARY

Well No.	GL Elev. (ft MSL)	Top of Casing Elev. (ft MSL)	Total Depth Drilled (ft)	Steel Surface Casing Depth (ft BGL) <sup>a</sup>	Well Casing						Open Interval				Dedicated <sup>g</sup> Sampling Equipment
					Diam. (in)	Type <sup>b</sup>	Depth (ft BGL)	SC/OH <sup>c</sup>	Diam. (in)	Type <sup>b</sup>	Screen Interval (ft)	Slot Size (in)	Sand Pack Interval (ft)	Static <sup>d</sup> Water Level (ft BGL)	
WW-1	2605	2606.92	800	460	-	-	-	-	-	-	Plugged	-	-	-	
SW-1	2571	2573.19	220	8	4	ST	220	SC	4	SST	187.5-197.5	.020	-	191	SP
SW-2	2566	2567.11	204	20	4	ST	200	SC	4	SST	185-195	.010	180-204	185	SP
SW-3	2564	2565.89	202.5	20	4	ST	202.5	SC	4	SST	187-197	.010	182-202.5	187	SP
PCB-1	2568	2569.56	197	138	4	PVC	181	SC	4	PVC	181-191	.010	179-191	187	PB
PCB-2	2566	2567.69	200.5	138	4	PVC	184	SC	4	PVC	184-194	.010	181-197	186	PB
PCB-3	2561	2562.93	195	138	4	PVC	190	SC	4	PVC	175-185	.010	173-187	176	SP

<sup>a</sup>Feet below ground level.

<sup>b</sup>ST = steel, PVC = polyvinyl chloride, SST = stainless steel.

<sup>c</sup>SC = screen, OH = open hole.

<sup>d</sup>Typical water levels.

<sup>e</sup>High/low piezometers set in the same borehole.

<sup>f</sup>3/4-inch PVC piezometer installed in same borehole as 4-inch PVC.

<sup>g</sup>SP = Stainless steel pump, PB = PVC bailer.

All pumps are set at the bottom of the well screen.

casing was filled with cement grout. Above-water annular seals were placed from the surface. Annular seals beneath the water were tremied into place with one-inch ID steel pipe. The amount of annular fill was determined by periodically sounding the annulus as the seal material was being placed.

### E.3.3 SOIL SAMPLING METHODS

Soil samples were collected using a number of different methods. The methods were chosen based on practical applicability and on the objectives of the sampling. These methods are described below. The drilling logs for all wells and borings are provided in Appendix A.

Grab Samples. Grab samples of the cuttings from the air rotary drilled holes were taken for lithologic descriptions. These samples were disturbed and represented a homogenized sample over several feet. Bulk lithology changes were detected, but thinly bedded sequences could not be distinguished from the bulk lithology. For example, a section consisting of 3-inch-thick sand seams separated by 6-inch-thick clay seams would be logged as sandy clay. Dry drilling methods allowed better resolution of thinly bedded sections, but compositing of the samples still occurred. Grab samples were retained as composites of 5-foot intervals.

Split Spoon. Standard 2-inch OD and 3-inch OD steel split spoons were used to obtain soil samples at particular horizons at several wells and most borings. In the silo wells, split spoon samples were obtained at predetermined intervals for photodocumentation and laboratory analysis. In most of the geotechnical and deeper exploratory borings, split spoon samples were taken on 5-foot intervals. In Coreholes D-21,

D-22, D-23, and D-32, split spoons were driven on 5-foot intervals down to the depth where coring could begin, which was typically at 110 feet. The 2-inch OD split spoons were driven with a 140-pound hammer falling 30 inches in accordance with standard methods. Blow counts were recorded as the 2-inch spoon was advanced. The 3-inch OD sampler was also driven by a 140-pound hammer, but the spoon diameter and the driving lift and fall did not conform to standard procedures; thus, blow counts and relative densities were not obtained. The 3-inch spoon was used to obtain a sufficient soil sample volume for laboratory analysis without requiring repeated drives.

Core Samples. Several holes were cored over specific intervals. Core recovery varied from 50 to 100 percent. Beginning with Hole D-21, core recovery of the pertinent portions of the strata, usually the saturated sands, was improved markedly over earlier coring; recoveries of 85 to 100 percent were obtained in the later holes. Full core recovery greatly improved the understanding of the hydraulics of the groundwater system beneath the site. Portions of the cores have been submitted for soils laboratory analysis, including grain size distribution, permeabilities, and mineralogy.

*4 of 11  
Continuous  
sampling*

Other Methods. A shelby tube (thin-walled steel sleeve pushed into the soil) was used without success during the drilling of Well PCB-3. Clay beds present were too dense and the shelby tube deformed and crushed.

The driven drill bit auger method used to drill the silo test holes provided a dry and relatively undisturbed sample. Individual thin beds were disturbed during sample extraction, but bed resolution of less than 3 inches could be obtained and grab samples of unmixed horizons could be taken. This method was previously described as a special drilling method in Section E.3.1.

#### E.3.4 GEOPHYSICAL LOGGING

Most of the wells and borings drilled at the site were logged with downhole geophysical methods to aid in formation identification and geologic correlation. Borehole conditions were variable at the time the logs were run. Static water levels, hole size and stability, and surface casing conditions were not constant between wells. This variability complicated interpretations of the logs, but the geophysical responses recorded in the boreholes were useful in determining the hydrogeology of the site.

The typical suite of geophysical logs consisted of natural gamma radiation, short (16 inches) and long (64 inches) normal electrical resistivity, single-point resistivity, neutron porosity, and caliper. On the dry, open hole portions of some of the borings, dry hole resistivity logs were run. Other logs that were occasionally run included temperature, differential temperature, gamma-gamma density, and spontaneous potential (SP). The single-point resistivity and the caliper logs were sufficiently sensitive to distinguish the thin sand beds in the clayey section beneath the site.

To establish correlation between the geophysical logs and the geological section, several coreholes were logged before they were plugged or converted to a well. From the correlations established between the geophysical logs and cores, it was possible to extend geologic correlations to air rotary drilled holes. The logs capable of resolving beds less than one foot thick were the most useful. Table E.3-3 provides a list of the geophysical logs and depth intervals of the geophysical logging done during this investigation. The logs are contained in Appendix C.

Table E.3-3  
SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

JUNE 6 through JUNE 8, 1984

Well or Boring No.	Total Depth Cased (ft) <sup>a</sup>	Logs Run	Logged Interval (ft)	Comments
D-3	100	GR EL	0-375 0-396	Clays swelled in at 260 feet
D-4	122	G GR N HRD E EL C	0-375 0-375 0-381 0-393 122-375 122-375 0-390	Hole washed out badly
D-10	138	G GR N HRD E EL C	0-395 0-395 0-401 0-399 138-395 138-395 0-390	
MW-8	213	G GR N HRD E EL C	0-210 0-210 0-216 0-220 213-220 213-220 0-227	
D-9	138	G GR N HRD E	0-210 0-210 0-246 0-246 138-240	
MW-10	118	T	100-234	
MW-11	120	G GR N HRD E EL C T	0-244 0-244 0-250 0-249 120-244 120-244 0-245 125-251	
MW-12	120	T	125-238	

Table E.3-3 (continued)  
 SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

AUGUST 5 through AUGUST 14, 1984

Well or Boring No.	Total Depth Cased (ft) <sup>a</sup>	Logs Run	Logged Interval (ft)	Comments
D-3	102	GR	0-365	Well sloughed to 370 feet  Swelling clay at 260 feet
		EL	169-365	
		G	0-369	
		N	0-370	
		E	169-364	
		G	0-357	
		HRD	5-364	
		C	0-360	
D-4	122	GR	0-342	Well sloughed to 347 feet
		G	0-340	
		N	0-347	
		E	147-340	
		G	0-340	
		HRD	5-347	
		C	0-340	
D-8	144	G	0-334	
		GR	0-340	
		N	0-334	
		HRD	0-334	
		E	130-334	
		EL	108-340	
		C	0-340	
D-9 (Logged to check equipment)	122	GR	0-366	Well sloughed to 370 feet
		EL	197-366	
		G	0-360	
		N	7-367	
		E	197-367	
		G	0-362	
		HRD	0-370	
		C	0-370	
D-10	140	GR	0-350	Well sloughed to 356 feet
		EL	193-350	
		G	0-346	
		N	7-354	
		E	193-346	
		G (2)	0-238	
		HRD	0-356	
		C	0-349	

Table E.3-3 (continued)  
 SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

AUGUST 5 through AUGUST 14, 1984

Well or Boring No.	Total Depth Cased (ft) <sup>a</sup>	Logs Run	Logged Interval (ft)	Comments
MW-7	140	GR	0-256	Hole redrilled with mud
		E	140-256	
		EL	140-256	
		G	0-254	
		N	0-261	
		HRD	0-261	
		C	0-260	
MW-8A	120	GR	0-130	Well sloughed to 136 feet; not redrilled Dry hole
		EL	Dry hole no log	
		G	0-128	
		N	6-135	
		G	0-129	
		HRD	6-136	
		E	Dry hole no log	
		C	0-134	
MW-9 (Logged twice; before and after hole cleaned out)	138	GR	0-256	
		EL	138-256	
		E	138-256	
		G	0-256	
		N	0-263	
		HRD	0-258	
		C	0-240	
MW-10	120	GR	0-220	
		EL	120-229	
		G	0-229	
		N	0-235	
		HRD	0-236	
		E	0-180	
MW-12	120	GR	0-257	Logged on 08/08/85 and again on 08/09/85 after cleanout. Log of 08/09/85 presented.
		EL	239-259	
		G	0-259	
		N	0-265	
		HRD	0-264	
		C	0-262	
E	239-259			

Table E.3-3 (continued)  
 SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

OCTOBER 4 through OCTOBER 26, 1984

Well or Boring No.	Total Depth Cased (ft) <sup>a</sup>	Logs Run	Logged Interval (ft)	Comments
D-15	158	G	0-250	
		GR	0-251	
		N	6-256	
		EL	158-251	
		E	158-250	
D-17	117	G	0-284	
		GR	0-282	
		N	67-290	
		E	73-284	
		HRD	3-286	
MW-13	158	G	0-290	
		GR	0-293	
		N	42-297	
		EL	1-204	
		E	12-291	
		HRD	7-297	
MW-14	158	C	0-292	
		G	0-282	
		GR	0-284	
		N	10-289	
		E	15-283	
WW-1		G	0-367	Upper 400 feet logged before casing set. Bottom 400 feet of hole not logged because of hole collapse.
		GR	0-368	
		N	6-384	
		EL	0-368	
		E	0-368	
SW-1	8	HRD	3-362	
		G	0-211	
		N	6-217	
		E	192-212	

Table E.3-3 (continued)  
SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

JANUARY 8 through JANUARY 9, 1985

<u>Well or Boring No.</u>	<u>Total Depth Cased<sup>a</sup> (ft)</u>	<u>Logs Run</u>	<u>Logged Interval (ft)</u>	<u>Comments</u>
D-17	250	T	190-240	
D-18	215	T	160-215	
MW-4	139	T	190-230	
MW-9	138	T	180-252	
MW-10	225	T	160-240	
MW-11	240	T	180-240	
MW-12	250	T	190-250	
MW-13	158	T	180-268	
MW-14	158	T	150-257	

Table E.3-3 (continued)  
 SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

APRIL 3 through APRIL 15, 1985

Well or Boring No.	Total Depth Cased (ft) <sup>a</sup>	Logs Run	Logged Interval (ft)	Comments
D-20	137	G	0-349	
		N	0-356	
		E	0-349	
		T	0-355	
D-21	118	G	0-291	
		N	0-298	
		E	0-291	
D-22	-	G	0-284	
		N	0-290	
		E	0-284	
		T	0-289	

APRIL 15 through APRIL 16, 1985

D-23	130	G	0-305	
		N	0-302	Neutron broke down at 202 feet
		E	0-305	
		C	0-312	3-inch casing to 130 feet
D-24	118	G	0-267	
		N	0-274	Neutron failed at water level
		E	0-264	
		C	0-275	Caliper stuck in mud at 275 feet

Table E.3-3 (continued)  
 SCHEDULE OF GEOPHYSICAL LOGS RUN AT ESII SITE B

OCTOBER 5 through OCTOBER 7, 1985

Well or Boring No.	Total Depth Cased (ft) <sup>a</sup>	Logs Run	Logged Interval (ft)	Comments
D-27	100	GR	0-279.5	
		E	221-279.5	
		C	0-276	
		N	0-276	
		DR	100-220	
		SP	221-279.5	
D-28	100	GR	0-278	
		E	236-278	
		C	0-278	
		N	0-278	
		DR	100-236	
		SP	236-270	
D-29	94	GR	0-278	
		E	250-278	
		C	0-277	
		N	0-277	
		DR	94-252	
		SP	250-278	
D-30	99	GR	0-293	
		E	275-293	
		C	100-293	
		N	0-293	
		DR	100-292	
		SP	274-293	
D-32	115	GR	0-293	
		E	115-293	
		N	0-293	
		SP	115-293	

<sup>a</sup>Values for total depth cased are those that were present at time of logging.

Explanation of geophysical log abbreviations:

- GR Natural gamma radiation, large crystal detector
- G Natural gamma radiation, small crystal detector
- N Neutron porosity
- HRD High resolution density (gamma-gamma)
- E Single-point resistivity
- EL 64-inch-long normal resistivity
- C Three-arm caliper
- T Static temperature
- DR Dry hole resistance
- SP Spontaneous potential

### E.3.5 WATER SAMPLING

Water samples were taken from all the wells that were installed during this investigation. For the identified RCRA monitoring wells, a monthly sampling schedule was followed for over two years. Samples from the RCRA monitoring wells have been analyzed for the required interim status groundwater list plus an agreed-upon list of organic compounds on the EPA's priority pollutant list. Test wells and the monitoring wells have also been sampled for naturally occurring common ions and metals to aid in the resolution of the aquifer system.

Well sampling methods have varied depending on the well construction and aquifer yield. All wells routinely monitored for RCRA or other regulatory requirements have dedicated sampling equipment. Either PVC or stainless steel bailers with a bottom check valve or all-stainless-steel electric submersible pumps are installed. Table E.3-2 indicates the sampling equipment used at each monitoring well. Test wells were sampled with a 3-inch ID stainless steel bailer 20 feet long. The bailer was raised and lowered by a vinyl-coated stainless steel cable and a winch on a contractor's pump service truck.

*Review re: yellow  
bailers! bladder  
pumps.*

For purposes of this investigation, presample purging of low-yield wells was accomplished by bailing or pumping the wells dry then sampling after sufficient water had reentered the well to obtain the required volume for the samples. Typically, the low-yield wells required at least 6 hours of recovery before sampling. Procedurally, the low-yield wells were evacuated first, then the other wells were sampled and the first wells were allowed to recover. The higher-yielding wells were pumped at one to 5 gpm, until at least two casing

volumes of water had been removed. Once an operational sampling procedure had been determined for each well, all subsequent samples were collected following the same procedure. Field parameters of temperature, specific conductance, and pH were measured on the water sample collected from each well.

#### E.3.6 DECONTAMINATION PROCEDURES

To minimize the potential of cross contamination between drill holes and samples, common equipment used between holes or wells was decontaminated before and after each use. High-pressure hot water and steam were used to clean the drilling equipment. All down-hole tools and drill pipes were cleaned rigorously between holes. The operational part of the drill rig, including the cables, hydraulic hoses, and rotary table, was also cleaned between holes. Any petroleum products visible after rig maintenance or seepage during operations were removed. This minimized the potential transfer of this material into the well or onto the well casing. Leaking hydraulic lines were repaired or replaced as soon as they were noticed. Contamination from drill rig fluids has never been detected in the water or soil samples.

Water and soil sampling equipment were cleaned before and after use by high-pressure hot water and trisodium phosphate (TSP) solutions. Distilled water was used for final rinsing of the sampling equipment. All equipment used to transfer samples to the sample bottle was cleaned in the same manner. Samples from wells equipped with pumps were taken directly from the pump discharge.

Geophysical logging tools and the cable were cleaned with high-pressure hot water and TSP wash and rinsed with distilled water before the first use. Approximately 400 feet

of logging cable was stripped off the drum and cleaned. With 400 feet of the cable off, the drum was wrapped with a polyethylene plastic sheet (Visqueen) to prevent potential contamination of the well by underlying and unused wraps of cable. The cleaned cable was then rewound onto the drum. Between holes, the tools and cable were washed with TSP and rinsed with distilled water. At the end of the job, the tools, cable, and cable draw works were washed with TSP and high-pressure hot water.

#### E.3.7 PHYSICAL TESTING

Many of the soil samples taken during the drilling of the wells and borings installed in this investigation were subjected to various laboratory tests to determine physical properties. Standard laboratory procedures were used to determine grain-size distribution, moisture contents, percent saturation, porosity, and atterberg limits (plasticity). The results of these tests are provided in Appendix G and discussed in Section E.4.

#### E.3.8 AQUIFER TEST METHODS

The aquifers beneath the site are thin, low-yielding, fine-grained silty sands. A variety of test methods have been used to estimate the aquifer hydraulic properties of these sands and the intervening clays. The aquifer test data are provided in Appendix D. The following is a summary of aquifer test methods. Additional detailed explanations are given in Section E.4.

Pumping Tests. Wells along the north and northwest sides of the site yield enough water to run constant-rate pumping tests. Two- to 5-hour, single-well pumping and recovery tests were run in which water-level changes in the aquifer,

with time during and after pumping, were used to estimate aquifer transmissivity. Hydraulic conductivity values were calculated from the transmissivities on the basis of measured saturated thicknesses.

Slug Tests. Most of the wells did not yield enough water to maintain constant pumping rates. In those wells, a slug of water was removed, and the recovery of water level in the well with time was used to estimate transmissivities and a calculated hydraulic conductivity. Slug removal with pumps resulted in part of the removed slug being contributed by the formation. This violates the assumptions of conventional slug test analytical methods. To analyze these tests, it was necessary to use methods developed by researchers for the coal and mineral industries.

Borehole Packer Tests. Single- and double-packer tests were conducted in some of the coreholes. In this method, a discrete portion of the borehole was isolated by inflatable packers. The amount of water that was pumped into the formation, with time and under varied pressures, was used to calculate a composite permeability for the tested section.

Laboratory Permeability Tests. Selected portions of cores were subjected to triaxial permeability testing in the soils laboratory. Constant head permeabilities were determined using standard test methods. Vertical permeabilities were tested by this method.

### E.3.9 WATER-LEVEL MONITORING AND OTHER INSTRUMENTATION

Water levels in the wells were measured immediately before sampling (or periodically if the well is not sampled regularly). Two-conductor, electric water-level measuring devices manufactured by Powers, Soil Test, and Olympus were used.

Stevens Type F water-level recorders were installed on Wells MW-9, MW-11, and MW-12 in late September 1984. Approximately 2 months of continuous water levels were obtained from these instruments. A recording barometer was established while the water-level recorders were running, and barometric efficiencies for the wells were determined. Water level data, including the recorder charts and barometric data, are provided in Appendix E.

To determine if periodic water quality changes were occurring, Wells MW-10 and MW-12 were also equipped with a Yellow Springs Instrument electrical conductivity and temperature probe and a Campbell Scientific Data Logger. During the test, conductivity and temperature measurements were made every 30 minutes. The probes were set at the top of the water and in the middle of the screened portion of the well. Two to 3 weeks of data were obtained at each setting. The trend plots and recorded conductivity and temperature data are provided in Appendix F.

#### E.3.10 SOIL MINERALOGY

Whole-rock mineralogy was determined on selected core samples by X-ray diffraction methods. This was done using standard mineralogy techniques and was used to determine the species of minerals present as an aid to understanding the hydrochemistry of the site. Total organic carbon determinations and rock evaluation analysis were also conducted to provide additional data on the hydrochemical conditions of the soils underlying the site. These data are discussed in Section E.4.3.

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#### E.4 SITE CHARACTERIZATION

The regional and local hydrogeologic setting for the Site B area was presented in Section E.2. It is evident from the regional information that the uppermost water-bearing zone beneath Site B is the saturated portion of the Glenns Ferry Formation. Here, groundwater is typically encountered at depths exceeding 180 feet.

*Water zone*

In this section, the results of the site-specific hydrogeologic investigations conducted at Site B are presented in detail. The goal of this investigation is to characterize the geologic and hydrogeologic properties of the uppermost aquifer and any aquifer hydraulically connected to it. At Site B this involved a detailed investigation of the upper 400 feet of unconsolidated sediments beneath the site. This information has been assembled pursuant to 40 CFR 270.14(c)(2).

The uppermost water-bearing zone beneath Site B actually consists of two discrete, low-yielding, finely bedded sand zones that are separated by a 20- to 30-foot-thick confining clay bed. Under the nomenclature used in this report, these two zones are called the upper and lower aquifers, respectively. Both zones occur in the Glenns Ferry Formation.

An unsaturated zone, ranging from 140 to 200 feet in thickness, overlies the uppermost aquifer and consists of silts and clays of the Glenns Ferry Formation overlain by coarser-grained sands, silty sands, dense clay beds, and sandy gravels of the Bruneau Formation.

The following sections develop in detail the generalized concepts presented above. A description of the site-specific subsurface geology is provided, followed by a detailed examination of the hydraulic and hydrochemical aspects of the

uppermost aquifer system. The system is complex. This results from the subtle stratigraphic nature of the Glenns Ferry Formation and the effect of dipping strata. To orient the reader, a diagrammatic overview of the uppermost aquifer concept is presented in Section E.4.3, following the site-specific geology discussion below.

#### E.4.1 SITE GEOLOGY

##### E.4.1.1 FORMATION IDENTIFICATION

Quaternary and Tertiary sediments of the Bruneau and Glenns Ferry Formations directly underlie the site. The veneer of surficial gravels present over much of the site is interpreted as basal conglomerate of the Pleistocene-Age Bruneau Formation (Benfer, 1984). Fine-grained sediments of the Pliocene- to Pleistocene-Age Glenns Ferry Formation underlie the Bruneau Formation gravels. The Glenns Ferry then persists throughout the remaining depth of the investigation.

##### E.4.1.2 STRATIGRAPHY

Geologic protocol describes the stratigraphy of a study area in ascending order from <sup>lower to upper sediments, usually</sup> older to younger. However, this report will describe the geology of the site from the surface down (i.e., younger to older), since that is the order of importance and concern.

Throughout the remainder of this section, references will be made to the observed thicknesses of various geologic strata penetrated. Qualitative descriptive terms have been numerically classified according to Krumbein and Sloss (1963); and are shown in Table E.4-1. Unless an actual numeric thickness is reported in the text, the reader should use Table E.4-1 to identify the thickness ranges represented by the qualitative descriptive terms.

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Table E.4-1  
DEFINITION OF BEDDING

Definition of bedding is that adopted in Krumbein and Sloss (1963) and is presented here for the purpose of discussion.

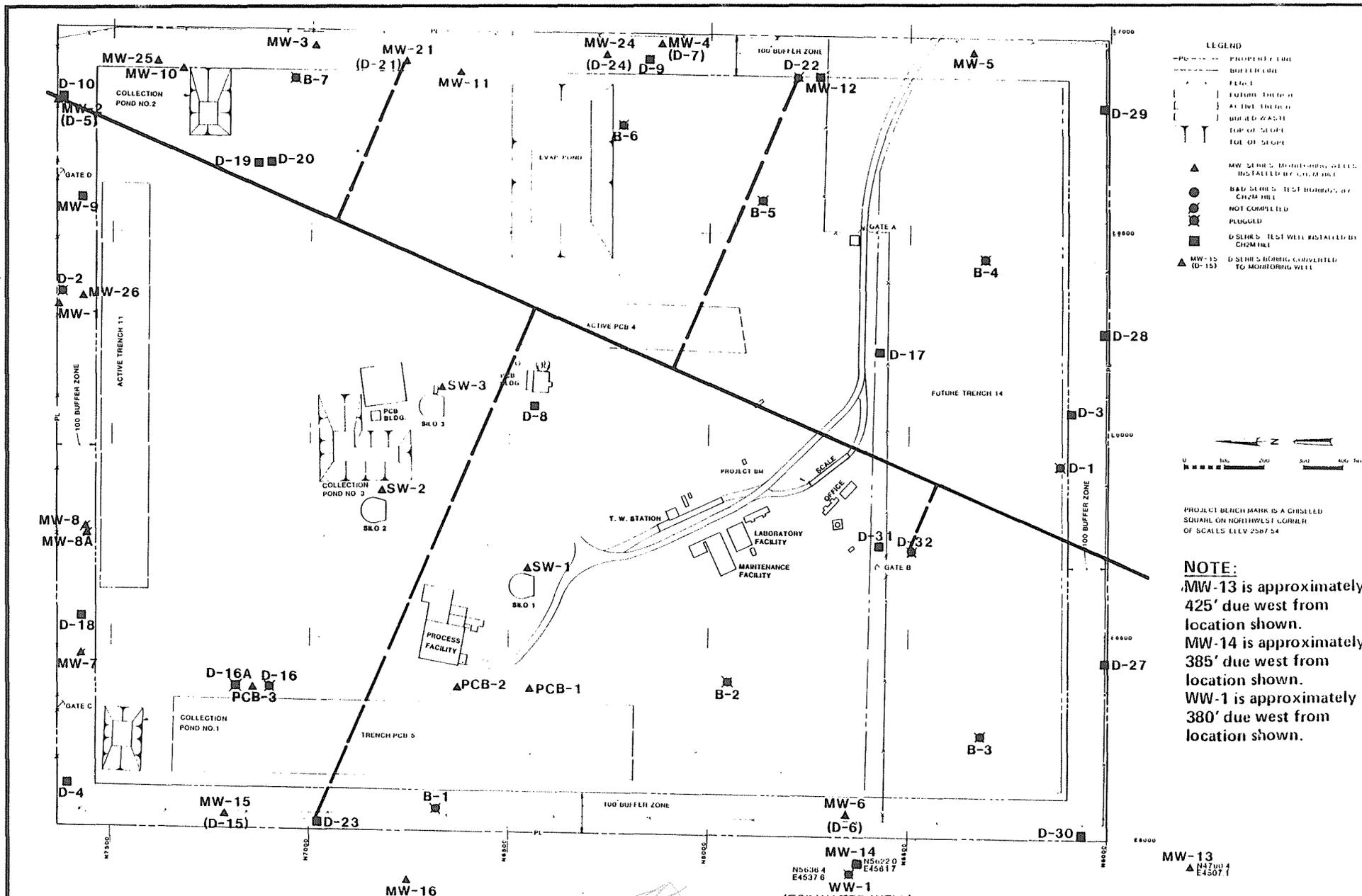
4 ft - 32 ft	Very thick-bedded
2 ft - 4 ft	Thick-bedded
2 in - 2 ft	Thin-bedded
1/4 in - 2 in	Very thin-bedded
0.2 cm - 1/4 in	Laminated
0.1 cm - 0.2 cm	Thinly laminated

---

Geologic logs from the boreholes that were installed during this and previous investigations of the site were used to construct geologic cross sections. Figure E.4-1 provides a plan view of the site showing the line of geologic sections. Stratigraphic sections of coreholes drawn along the predominant structural attitude are shown in Figure E.4-2, and provided as Plate E.4-1.

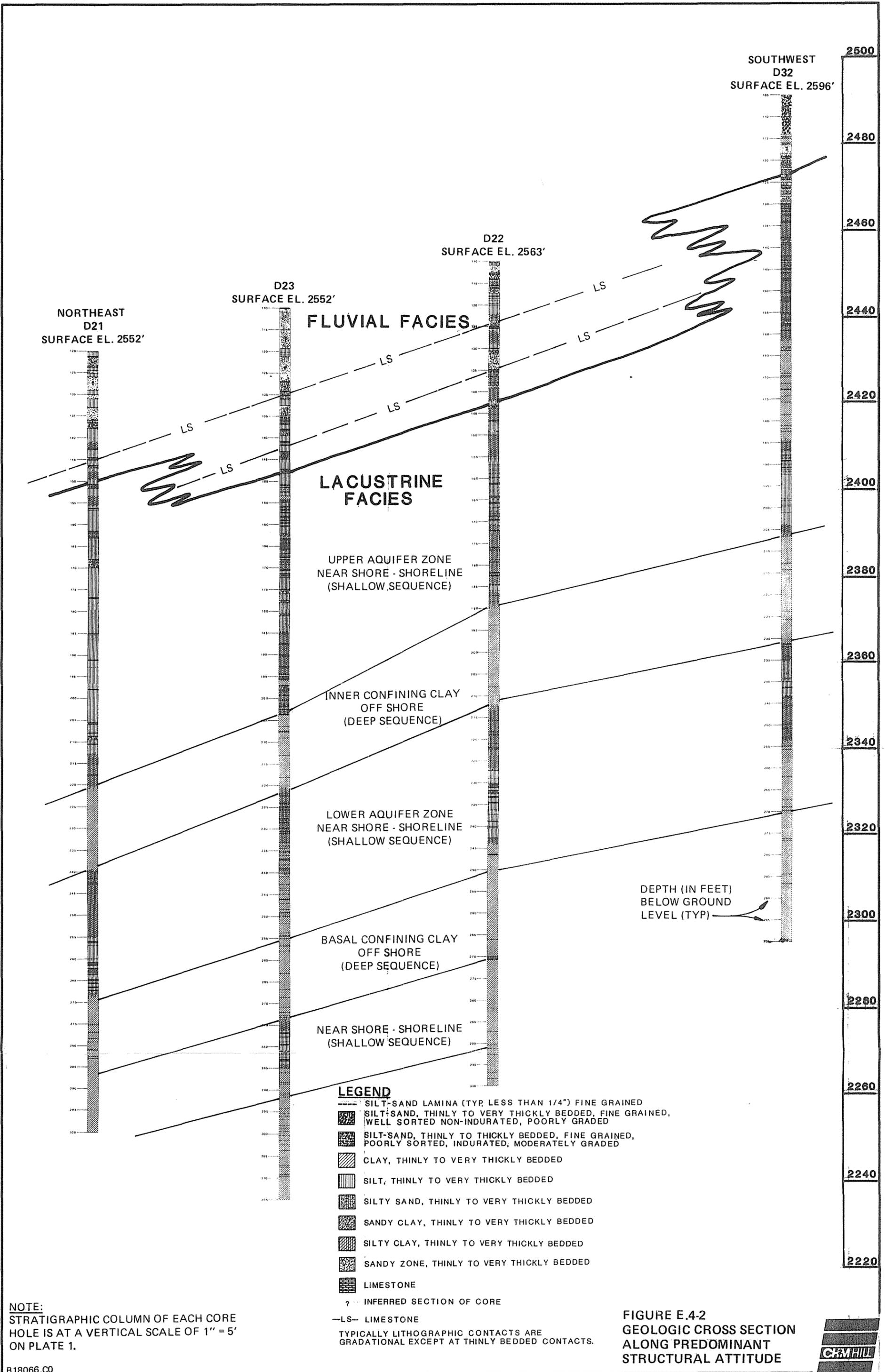
With two minor exceptions, the basal gravels of the Bruneau overlie the entire site. The exceptions are where the basal gravels are thinly covered by recent soil or ash layers, or where they have been removed by site construction activities. Typically, the gravels extend only to about 50 feet. The thickest gravels were noted at MW-5 (103 feet) and MW-9 (108 feet) in the southeast and northeast corners of the study area, respectively. Surface gravel was not present at D-30.

The Glenns Ferry is present beneath the Bruneau gravels and represents sedimentary deposition in a large lake system with peripheral and capping fluvial and flood plain facies (Smith et al., 1982). As such, the Glenns Ferry consists of lake-margin deposits containing fluvial deposits (stream and beach shoreline sands and near-shore silts). Underlying the



**FIGURE E-4.1**  
**LINE OF GEOLOGIC SECTION**  
**PROJECTED ALONG PREDOMINANT**  
**STRUCTURAL ATTITUDE**





NOTE:  
STRATIGRAPHIC COLUMN OF EACH CORE  
HOLE IS AT A VERTICAL SCALE OF 1" = 5'  
ON PLATE 1.

FIGURE E.4-2  
GEOLOGIC CROSS SECTION  
ALONG PREDOMINANT  
STRUCTURAL ATTITUDE

fluvial deposits are the lacustrine facies (lake deposits) of the Glenns Ferry. The entire sequence exhibits upward coarsening (finer grained with depth). As such, this represents a period of lake regression (a lowering of the water level in the ancient lake [Selley, 1972]). Lithologic and facies contacts are gradual and are controlled by the predominance of grain size and bedding.

fine?  
sharp contacts

The upper (fluvial) sequence of the Glenns Ferry Formation contains very thick-bedded (greater than 10 feet) fine sands and silts containing a few clay seams. Typically, the sands are well sorted, moderately indurated, and thickly bedded. Calcite cementing predominates. The clay seams distributed within the sand are generally thin-bedded (several inches to one foot thick) and are plastic (soft and moldable). Near the base of the sequence, thin-bedded carbonates (limestone) occur. These sedimentary sequences are representative of lake margin environments (Selley, 1972). This section persists to approximately 130 feet in depth at the center of the site, where the finer grain size and thinner bedding exists. Where the predominance of finer grain size and thinner bedding exists, this facies change is interpreted as the bottom contact of the fluvial facies overlying lacustrine sediments of the Glenns Ferry Formation.

Revised

The lacustrine facies consists of thick-bedded clays and silts containing thin beds of silt, sand, and sand-silt lamina (generally less than one foot thick). The sequence expresses cyclic sedimentation for the depth investigated. The formation transcends through thick-bedded sequences of clay and silts containing discrete, thinly bedded sands (one foot thick or less) and reflects deposition representative of a lacustrine environment as the lake waters rose and fell. The sands and silts (linear and lense-like in form) represent near-shore and shoreline deposits. Portions of

this sequence are deltaic in nature and contain abundant plant debris. Sheet-like clay and finer silts are representative of offshore and deeper lacustrine deposition.

The first sequence of shoreline and near-shore deposits underlying the fluvial facies occurs at an approximate depth of 160 feet at the center of the site. In the northwest portion of the site, the sequence contains numerous thin-bedded silty sands and lamina that are separated by thin- to thick-bedded silts and clays. These sandbeds appear to pinch and thin toward the south and east, forming thickly bedded clay and silt in those directions. Although a continuous zone exists, individual sandbeds appear discontinuous across the site. This may indicate that the source of the sands was from the northwest, where increased bedding and coarser grain sizes would be expected. This may also be a result of a lateral facies change, such as a transition to a flood plain or deltaic sequence, occurring within the northern portion of the site, or may represent younger deposition upon paleo erosional surfaces. It is this zone of thin, discontinuous, and laterally variable sands and silts that represents the upper aquifer. Within the upper portion of the sequence, the unit changes color from brown to grey. Such a color change may represent a change from oxidizing to reducing conditions at the time of deposition.

These near-shore deposits transcend into offshore (deep lake) deposits consisting of thickly bedded clay containing silt. This clay unit is approximately 20 feet thick at the center of the site, extending to a depth of approximately 230 feet. This zone thins from approximately 20 feet thick in the northwest portion of the site to more than 30 feet thick in the southeast portion of the site. This unit is the confining bed separating the upper and lower aquifers.

This offshore deposit transcends into another shoreline and near-shore sequence, generally comprising thick-bedded silt and thin-bedded clay that contain thin-bedded sands and sand lamina. This zone (the lower aquifer) is continuous across the site, although some individual sandbeds may gradually thin and pinch out. This unit extends to a depth of approximately 250 feet, where again, deposition transcends into deeper offshore deposits of thick-bedded clay and fine silt, which provide the basal confinement of the lower aquifer. It appears from the limited information and from the deep borings that this facies again transcends into another sequence of near-shore sands and silts at approximately 290 feet in depth. These sands are very thin-bedded.

The drilling logs of the deep artesian well onsite and the 800-foot-deep exploratory water well southwest of the site indicate that the strata below 300 feet are predominantly blue clay and shale to at least 1,770 feet.

#### E.4.1.3 STRUCTURE

Units of the Glens Ferry Formation at the site strike north 69 degrees west, and dip approximately 3.5 degrees to the northeast. Gradual differences have been noted within the formation and reflect changes in depositional environment reflective of lacustrine sedimentation and Snake River Plain downwarping. The upper near-shore sequence (i.e., the upper aquifer measured at its base) strikes north 70 degrees west and dips 1.8 degrees northeast. The next near-shore sequence (i.e., the lower aquifer measured at its center) strikes north 70 degrees west and dips 2.4 degrees northeast, as measured from Coreholes D-32, D-22, and D-21.

No evidence of faulting exists within the depths of the investigation at the site as determined by surface mapping

of existing trenches and analysis of geologic cores. Units can be traced across the site using geophysical logs and direct core logs, all of which conform to measured strike and dips. No indications of faulting (such as displacement, associated fracturing, or alteration) have been witnessed throughout the entire geologic section investigated.

*Vadose zone characteristics*

#### E.4.2 SITE HYDROGEOLOGY

*Re number sections*

Identification of the uppermost aquifer is pursuant to 40 CFR 264.95(a) and 270.14(c)(2). Of primary interest in this investigation are the water-bearing characteristics of the Glenns Ferry Formation, which underlies the site. Two water-bearing sand sequences were identified in the sedimentary unit of the Glenns Ferry. Although not aquifers in the normal sense of the word, they do represent water-saturated media and are therefore potential migration pathways beneath the site. Because of the definition of the uppermost aquifer in the regulatory context, they represent the uppermost aquifer for groundwater monitoring purposes.

Section E.4.1 of this report described the geologic framework of the upper 800 to 1,600 feet of sediments. This section, E.4.2, will describe in detail the hydrologic and hydrochemical properties of the two sand zones that have been defined as uppermost aquifer(s) beneath the site.

##### E.4.2.1 OVERVIEW

Two water-bearing zones have been identified within the Glenns Ferry Formation, both of which are important to the site. These two zones have been denoted as the upper and lower aquifers. Figure E.4-3 is a diagrammatic cross section showing the upper and lower aquifers at the site. The upper aquifer consists of 3 to 8 cumulative feet of finely

NORTHEAST

SOUTHWEST

SITE LOCATION (APPROX)

GROUND LEVEL

BRUNEAU FORMATION  
50'± GRAVELS

GLENNS FERRY FORMATION  
100'± FLUVIAL SANDS AND CLAY

BEDDED FINE SANDS WITH SILT AND CLAY  
CONFINING ZONES  
UPPER AQUIFER (3' TO 8' CUMULATIVE SAND THICKNESS)

INTERMEDIATE CLAY (CONFINING ZONE)

LOWER AQUIFER (4' CUMULATIVE SAND THICKNESS)  
THICK BEDDED CLAY (CONFINING ZONE)

SATURATED THICKNESS  
0-60'

TOTAL THICKNESS  
80-90'

20-30'

15'

POTENTIOMETRIC SURFACE

NOTE:  
GROUNDWATER FLOW DIRECTION IS INTO THE DRAWING (EAST). DIP IS EXAGGERATED FOR ILLUSTRATIVE PURPOSES.

FIGURE E.4-3  
DIAGRAMMATIC CROSS SECTION  
UPPER AND LOWER AQUIFERS  
(NOT TO SCALE)



bedded, fine, silty, sand in 80 to 90 feet of silt and clay. The top of the upper aquifer sequence is a gradational contact with the overlying fluvial facies of the Glenns Ferry Formation. The top of the upper aquifer section is 120 to 160 feet below ground level. A massive clay 20 to 30 feet thick hydraulically separates the upper aquifer from another group of fine, silty, clayey sands. This second group of bedded sands is the lower aquifer. The top of the lower aquifer is 220 to 275 feet below ground level and the aquifer section is 30 to 40 feet thick. Because of structural dip, both aquifers slope to the northeast at approximately 2 to 4 degrees.

As a result of the northeasterly structural dip, the upper aquifer gradually emerges out of the water and grades from confined to unconfined to unsaturated from north to south. The entire upper aquifer becomes unsaturated along a general east-west trend that crosses the south-central portion of the site. South of this emergence, the upper aquifer sands are present but they are above the potentiometric surface and not saturated.

The top of the saturated upper aquifer is defined by the potentiometric surface since, because of the dip, an increasing thickness of the upper aquifer section becomes saturated to the north. Individual sand seams well above saturation along the southern limits of the aquifer intercept the potentiometric surface and become saturated along the northern side of the site. To the north and along the northern boundary, the lower sands in the aquifer are fully saturated and water levels rise 5 to 45 feet above the top of the sandbeds. The potentiometric surface of the upper aquifer varies from 140 to about 200 feet below ground level.

Groundwater in the upper aquifer flows into the site all along the northern border, but most enters from the northwest corner. Flow in the upper aquifer is to the east and southeast. The upper aquifer in the northwest corner has the highest transmissivity and is capable of yielding 5 to 10 gallons per minute (gpm). Along the eastern side of the site the upper aquifer yields less than 3 gpm, and along the saturated-to-unsaturated transition zone the aquifer yields less than one gpm.

The lower aquifer is saturated beneath the entire site. It consists of up to 4 feet of cumulative sand thickness in a 30- to 40-foot-thick section of bedded silts and clays. The sandbeds range from approximately one foot to less than one-sixteenth inch thick. Most sandbeds are found within a 15-foot-thick section of silts and clays. The permeabilities of the lower aquifer are low, and well yields are generally less than one gpm. Clay content increases to the south, and the lower aquifer is less transmissive beneath the southern margin of the site. Water in the lower aquifer is under moderate artesian pressure. Along the northern edge of the site, water levels rise 60 to 80 feet above the top of the aquifer. Groundwater in the lower aquifer flows to the northeast.

#### E.4.2.2 AQUIFER DESCRIPTIONS

As indicated, the upper aquifer is not saturated across the southern half of the site. Where the sands are not saturated, they do not meet EPA's RCRA definition of an aquifer. However, they will be identified as the upper aquifer in order to be consistent in references to the aquifers at the site. The lower sequence of sands is saturated everywhere under the site and constitutes the lower aquifer.

Numerous wells and piezometers have been installed to characterize and monitor the upper and lower aquifers at the site. Because of hole stability difficulties and the subtle lithologic changes of the finely bedded sandy sections comprising the two aquifers, the screened portions of some of the earlier wells were not installed as precisely in the aquifers as desired. Detailed coring allowed more accurate projections and identification of proper depth intervals for screen settings and sand packs.

The sampling interval of a well is dependent on where the sand seams that produce water are in relation to the screen and sand-packed interval of the well. Where saturated sand seams are adjacent to the screen, they will contribute almost all the water entering the well. If the screen is set above saturated sands or adjacent to the confining beds, water will enter the well through the sand pack. Both situations are present in the wells installed at this site.

Figures E.4-4 and E.4-5 present detailed cross sections of the hydrogeologic relationship of the upper and lower aquifers and their confining beds at ESII's Site B. Well completion intervals are shown on these figures. Aquifer intervals for some wells have been obtained by projecting into the measured strike and dip planes of the upper and lower aquifers that were identified from other coreholes and geophysical logs.

#### E.4.2.2.1 Upper Aquifer

The upper aquifer sequence consists of thinly bedded sands and sand lamina separated by thin- to thick-bedded silts and clays. The individual sand seams range from less than 1.5 feet thick to partings less than one-sixteenth of an inch thick. Most are between 0.5 and 0.1 foot thick and consist of very fine-grained, silty sand. Lateral continuity of individual

sands is difficult to demonstrate but the aquifer sequence is present across the entire site.

The bottom of the aquifer sequence is represented by a relatively rapid gradational change from silty clay to the massive clay of the underlying confining bed. The bottom of the upper aquifer section ranges from 185 to 250 feet below ground level. Water-bearing sands begin 5 to 13 feet above this gradational contact.

*2-4*  
*above?*  
The top of the upper aquifer is also a gradational contact. As discussed earlier, the upper aquifer is developed in the lacustrine facies of the Glens Ferry Formation. The contact between the lacustrine and overlying fluvial sediments is a gradational facies change represented by a thinning of beds and dominance of silts and clays from fluvial to lacustrine. The top of the lacustrine facies (top of the upper aquifer sequence) ranges from 120 feet below ground level in the northwest corner to about 160 feet below ground level in the northeast corner; across the central portion and eastern sides it is 120 to 140 feet below ground level. Thickness of the sequence ranges from 80 to 90 feet.

The top of the saturated water-bearing portion of this lacustrine sequence is a function of the structural dip (2 degrees to the northeast) and the potentiometric surface. Because of the dip, the section rises above the potentiometric surface and becomes unsaturated across the southern portion of the site. To the north, the dip causes progressively more sand seams to intercept the potentiometric surface and become saturated. Consequently, the saturated thickness of the aquifer increases to the north and the potentiometric surface rises up through the section. In addition to the effect of dip, the total cumulative thickness of the sandbeds changes laterally because of depositional variations.

In the northwest portion of the site, the cumulative thickness of bedded sand underlying the water table is about 8 feet, occurring over approximately 40 feet of fine- to thick-bedded silts and clays. It appears that the bedded sands thin and pinch toward the east and south (southeasterly), and some sandbeds may be discontinuous. Therefore, the upper aquifer becomes thinner and contains less sands to the east and south. The cumulative thickness of bedded sands underlying the water table in the eastern portion of the site is approximately 2 feet, occurring over approximately 25 feet of fine- to thick-bedded silts and clays. As indicated by the caliper log of D-10 (see Appendix C) and projections downdip from D-21, the cumulative sandbed thickness may be as much as 6 feet in the northeastern corner of the site.

Along the southern limit of the aquifer sequence and as individual sand seams within the sequence cross the potentiometric surface, the "aquifer" grades from unconfined to confined. Along the northern and central portions of the site, 3 to 5 feet of artesian head has been noted in the uppermost confined seams.

Confinement of the individual sands and the upper aquifer section is provided by 20 to 50 cumulative feet of silts and clays in beds ranging from one to 10 feet thick. The southern portion of the aquifer has more confinement than the northern portion because the potentiometric surface is low in the section, whereas along the northern border it is high in the section.

#### E.4.2.2.2 Intermediate Clay Bed

The inner confining clay between the upper and lower aquifers ranges from 20 to 30 feet thick across the site. As discussed in the previous section, the top of the inner confining clay is gradational with the silts of the bottom of the upper

aquifer. A similar transitional contact exists between the bottom of the confining clay and the top of the lower aquifer. In both cases, the gradational contact occurs within about 5 feet. This clay consists of blue-gray, massive to thickly bedded clay. In Corehole D-23, in the northwest corner, there are seven to ten silty sand lamina (less than 1/8 inch thick) within the 20-foot-thick clay; while along the east side no sand lamina are found in the entire 20-foot-thick section.

This clay unit is persistent and consistent across the site and hydraulically separates the upper and lower aquifers. This hydraulic separation is evidenced by differences in water level, flow directions, and water chemistry between the upper and lower aquifers. These indicators of hydraulic separation are discussed in more detail in subsequent sections of this report.

In addition to very low permeabilities, upper portions of the intermediate clay were also found to be at only 89.9 to 93.1 percent saturation. Lab test data are provided in Appendix G and are summarized in Table E.4-2. The lack of saturation also indicates that the two aquifers are not hydraulically connected through the bedded clay.

#### E.4.2.2.3 Lower Aquifer

The lower aquifer is a sand sequence within silts and clays of the Glenns Ferry Formation. Although the persistence and thickness of individual thinly bedded sands varies laterally, the aquifer is present and saturated everywhere beneath the site.

The bedded sands occur within a 30- to 40-foot-thick sequence of thick-bedded silts and clays. The majority of sands occur within a 10- to 15-foot interval. Coreholes and geophysical

*Return to  
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D-98  
D-99  
D-100*

Table E.4-2  
SUMMARY OF LABORATORY TEST RESULTS

Sample Number	Drill Hole Number	Depth in Feet	Vertical Coefficient of Permeability cm/sec	Dry Unit <sup>a</sup> Weight	Moisture <sup>b</sup> Content Percent	Specific Gravity	Degree of Saturation Percent	Porosity Percent
S-1	D-21	14.3-15.8			3			
S-2	D-21	24.2-25.0			4			
S-3	D-21	34.2-35.8			11			
S-4	D-21	44.2-45.4			21			
S-5	D-21	54.2-55.4			6			
S-6	D-21	64.2-65.6			7			
S-7	D-21	74.5-75.8			4			
S-8	D-21	84.2-85.1			7			
S-9	D-21	94.2-95.1			6			
S-11	D-21	138.0			32			
S-12	D-21	146.3			29			
S-13	D-21	156.0-156.8			32			
S-14	D-21	163.4-164.9	1 x 10 <sup>-7</sup>	97	26	2.691	91.9	
S-15	D-21	183.0-184.0	2 x 10 <sup>-6</sup>	96	30	2.703	97.3	
S-16	D-21	204.2-205.0	7 x 10 <sup>-7</sup>	92	29	2.703	95.8	
S-20	D-21	214.2-214.9	1 x 10 <sup>-6</sup>	95	29	2.778	96.8	
S-21	D-21	224.0-224.7	2 x 10 <sup>-6</sup>	98	23	2.609	89.9	
S-22	D-21	232.2-233.2	2 x 10 <sup>-7</sup>	98	28	2.791	98.7	
S-23	D-21	250.5-251.7	8 x 10 <sup>-8</sup>	98	27	2.743	99.9	
S-24*	D-21	256.2-256.5	U <sup>n</sup> t e s t a b l e					
S-25	D-21	258.7-259.3	2 x 10 <sup>-7</sup>	98	26	2.737 <sup>c</sup>	98.8	
S-29*	D-21	262.4-262.8	1 x 10 <sup>-5</sup>	93	24	2.70	--	45.0
S-33	D-21	269.3-270.0	1 x 10 <sup>-7</sup>	95	29	2.780	98.9	
S-35	D-21	278.0-278.5	4 x 10 <sup>-8</sup>	94	30	--	--	
S-36	D-21	287.0-289.0	5 x 10 <sup>-8</sup>	95	28	2.707	96.9	
S-1	D-22	10			6			
S-2	D-22	20			10			
S-3	D-22	30			4			
S-4	D-22	40			4			
S-5	D-22	50			3			
S-6	D-22	60			10			
S-7	D-22	70			4			
S-8	D-22	80			19			
S-9	D-22	90			3			
S-10	D-22	100			9			
S-11	D-22	110			17			
S-12	D-22	118.0-118.6			25			
S-13	D-22	144.0-144.6		95	28	2.777	95.5	
S-14	D-22	152.5-153.4	2 x 10 <sup>-7</sup>	95	28	2.758	95.8	
S-15	D-22	159.0-160.6	1 x 10 <sup>-6</sup>	98	19	2.771	69.6	
S-17	D-22	161.5-162.7	2 x 10 <sup>-6</sup>	98	24	2.760	85.5	
S-20	D-22	176.4-177.6	8 x 10 <sup>-7</sup>	95	26	2.764	87.2	
S-21	D-22	191.0-191.9	2 x 10 <sup>-7</sup>	96	27	2.756	91.4	

Table E.4-2 (Continued)  
SUMMARY OF LABORATORY TEST RESULTS

Sample Number	Drill Hole Number	Depth in Feet	Vertical Coefficient of Permeability cm/sec	Dry Unit <sup>a</sup> Weight	Moisture <sup>b</sup> Content Percent	Specific Gravity	Degree of Saturation Percent	Porosity Percent
S-22	D-22	216.5-217.4	1 x 10 <sup>-7</sup>	94	29	2.785	94.1	
S-23	D-22	228.7-229.2	3 x 10 <sup>-7</sup>	97	25	2.774	86.5	
S-24*	D-22	230.3-231.1	8 x 10 <sup>-6</sup>	98	28	2.778	98.7	
S-25*	D-22	231.7-232.8	1 x 10 <sup>-5</sup>	96	26	2.734	90.7	44.0
S-26*	D-22	233.3-233.5	2 x 10 <sup>-5</sup>	92	25	2.709	81.8	45.6
S-27	D-22	233.7-234.2	8 x 10 <sup>-7</sup>	98	26	2.725	95.3	
S-29	D-22	243.6-245.0	1 x 10 <sup>-7</sup>	94	26	2.752	86.7	
S-30	D-22	275.0-276.5	1 x 10 <sup>-7</sup>	95	26	2.728	89.4	
S-31	D-22	283.9-285.0	5 x 10 <sup>-5</sup>	97	25	2.719	90.7	42.8
S-1	D-23	10			3			
S-2	D-23	20			4			
S-3	D-23	30			6			
S-4	D-23	40			7			
S-5	D-23	50			7			
S-6	D-23	60			28			
S-7	D-23	70			6			
S-8	D-23	80			4			
S-9	D-23	90			11			
S-10	D-23	100			7			
S-11	D-23	146.5-146.9		86	32	2.66	90.9	
S-12	D-23	153.8-154.2	3 x 10 <sup>-7</sup>	91	31	2.73	97.4	
S-13	D-23	161.5-162.0	3 x 10 <sup>-7</sup>	95	29	2.79 <sup>c</sup>	96.0	
S-14*	D-23	168.2-168.8				2.70 <sup>c</sup>		45.0
S-15*	D-23	170.3-170.7	1 x 10 <sup>-4</sup>	95	27	2.70 <sup>c</sup>		43.4
S-16*	D-23	171.2-172.1	5 x 10 <sup>-5</sup>	96	27	2.70 <sup>c</sup>		43.1
S-17	D-23	176.8-177.2		96	28	2.79	97.7	
S-18	D-23	193.6-194.0		98	26	2.75	93.7	
S-19	D-23	208.0-208.4		92	31	2.76	97.4	
S-20	D-23	211.4-212.8	1 x 10 <sup>-7</sup>	92	29	2.74	93.1	
S-21	D-23	271.0-217.5		92	30	2.76	95.3	
S-22	D-23	221.4-231.9		93	29	2.76	93.5	
S-23	D-23	231.4-231.9		96	29	2.75	96.3	
S-24	D-23	241.9-242.7		94	29	2.75	94.0	
S-25	D-23	253.1-254.0	8 x 10 <sup>-8</sup>	93	29	2.74	94.9	
S-26	D-23	265.0-265.9		92	30	2.72	96.8	
S-27*	D-23	192.7-193.1	4 x 10 <sup>-5</sup>	96	23	2.70 <sup>c</sup>		42.9
Average								43.9

Notes: \*Sandbed

<sup>a</sup>pounds per cubic foot

<sup>b</sup>moisture contents for samples below 100 feet may have been affected by water used in rotary coring

<sup>c</sup>assumed value

logs of borings indicate that the bedded sands pinch and thin toward the west and south, forming very thin-bedded sands and sand lamina less than 1/4 inch thick. Some sands are discontinuous and pinch out. The total cumulative thickness of bedded sands in the western portion of the site is less than one foot.

Along the east side of the site the individual beds range from sand lamina (less than 1/4 inch thick) to one-foot-thick bedded sands, the latter consisting of fine- to very fine-grained silty sand. Most of the water is probably being carried in the upper portion of the sequence, where greater thickness and persistence exist. The total cumulative thickness of bedded sands in the lower aquifer along the eastern side is about 4 feet.

The top of the lower aquifer section is 205 to 275 feet below ground level, and the bottom is 305 to 250 feet below ground level. The lower aquifer section generally ranges from 30 to 40 feet thick.

#### E.4.2.2.4 Basal Confining Clay

Underlying the lower aquifer is a massive to thickly bedded clay at least 25 feet thick. This clay was penetrated in only a few borings, and it has not been tested extensively. Visual descriptions indicate it to be massive (does not contain sand lamina) and "fat," having high plasticity. Properties of this clay are expected to be similar to the inner confining clay.

#### E.4.2.3 AQUIFER PROPERTIES

Pursuant to 40 CFR 270.14(c)(2), aquifer tests were performed at ESII Site B to aid in the characterization of the site

hydrogeologic regime. The objectives of the testing program were twofold: (1) to examine the factors that influence the rate and direction of groundwater movement, (2) to evaluate overall groundwater availability, (3) to determine the degree of hydraulic separation of the upper and lower aquifers, and (4) to estimate the degree of containment afforded by the clays and other sediments found above and between the aquifers.

#### E.4.2.3.1 Methods of Investigation

The aquifer testing and evaluation program at the ESII site consisted of the following elements:

1. Packer testing of selected drill holes during initial well installation
2. Single-well constant discharge pumping tests, followed by the monitoring of well recoveries
3. Grain-size analyses of aquifer materials
4. Laboratory permeability testing of confining silt and clay zones
5. Routine water-level monitoring and subsequent construction of potentiometric surface maps

As of December 1985, 23 packer tests, 14 single-well pump tests, and 85 grain-size analyses were performed to characterize the subsurface groundwater flow regime. Table E.4-3 summarizes the data collected and identifies which wells and boreholes were tested. The results of the grain-size analyses and the water-level monitoring activities are presented in Appendixes A and E, respectively.

Table E.4-3  
AQUIFER CHARACTERIZATION PROGRAM SUMMARY

<u>Well or Borehole</u>	<u>Packer Test</u>	<u>Vertical Permeability Test</u>	<u>Single Well Aquifer Test</u>	<u>Grain Size Analysis</u>	<u>Water-Level Monitoring</u>
D-1				4 Total	
D-2	5 Total		x		
D-3	2 Total			7 Total	*
D-4	4 Total			9 Total	*
D-8	4 Total			8 Total	*
D-9	4 Total			10 Total	*
D-10	4 Total			9 Total	*
D-16A					*
D-17			xx		*
D-18			x		*
D-19					*
D-20					*
D-21				12 Total	
D-22		14 Total	x	17 Total	*
D-23		7 Total	x	9 Total	*
MW-1			xx		*
MW-2			xx		*
MW-3			xx		*
MW-4			xx		*
MW-5			xx		*
MW-6			xx		*
MW-9					*
MW-10			x		*
MW-11			x		*
MW-12			xx		*
MW-13					*
MW-14					*
MW-15			x		*
MW-21		11 Total	x		*
MW-24			x		*

x Sustained pumping rate maintained throughout test.  
 xx Well bore evacuated during test.  
 \* Indicates water levels measured on a periodic basis.

The pump tests provided the most meaningful data from which to compute groundwater flow rates. Groundwater velocities were determined in the project study area at 13 of 14 pump test locations. Five pump tests were conducted on the upper aquifer, five pump tests were conducted on the lower aquifer, and four pump tests were conducted on wells that span both the upper and lower aquifers. Section E.4.2.4.2 contains the results of the velocity computations derived from the pumping test program.

#### E.4.2.3.2 Pump Test Procedures

The pump tests were conducted as single-well constant discharge tests in which the well recoveries were monitored following the cessation of pumping. Because of the general low-yield characteristics of both aquifers, eight of the 14 test wells were readily dewatered during the tests.

Because of the generally low yields of the aquifers, installation of observation wells to conduct multiple well tests was not considered feasible. In order to detect changes in water levels, the observation wells would have to have been prohibitively near the production wells. Since many of the test wells are also monitoring wells, it was not considered appropriate to install another well within 10 feet of the monitoring well. Single well tests allowed many tests to be run giving good areal coverage without disturbing active or potential monitoring wells.

The pumping or bailing of the eight dewaterable wells was performed until the well bore was fully evacuated, at which point water-level recovery measurements were initiated. Typical times to evacuate the wells ranged from 1.7 to 8 minutes. The remaining five sustainable-yield wells were pumped at constant rates for 100 minutes or until sufficient drawdowns

from which to measure well recoveries were achieved.

Table E.4-3 denotes the eight wells that were evacuated and the five wells for which pumping rates could be maintained.

The drawdown and recovery of water levels in the wells were measured at regular intervals using an electric probe. The pumping or bailing rate was measured using a calibrated bucket and stopwatch. Average discharge rates were then calculated based on total volume evacuated over the total time period of pumping or bailing. Appendix D contains the discharge and recovery field data generated during the tests.

Methods for analyzing single-well pumping and recovery test data are presented by Theis (1935), McWhorter (1981), Hurr (1966), Logan (1964), and Zangar (1953). The Hurr, Logan, and Zangar techniques are approximation methods based on measurement of the specific capacity of a well and are not appropriate for detailed analyses beyond reconnaissance-level investigations.

By far the most common approach found in the literature for evaluating single-well pumping and recovery data is that of Theis (1935). This method is commonly referred to as the Standard Recovery Test and is fully discussed in classic texts such as Todd (1980), Ferris et al. (1962), and Kruseman and deRidder (1970). McWhorter, however, found that the Theis recovery test has limited application in situations where water-bearing strata exhibit low permeabilities and associated transmissivities (McWhorter, 1981). The Standard Recovery Test inherently assumes that the effects of well bore storage can be neglected during pumping and recovery. McWhorter demonstrated that well bore storage effects are important in the investigation of low permeability materials, and that the assumptions present in the Theis recovery test are no longer valid. He presents an exact analytic solution

to the Theis flow equation that gives full consideration to the complicating effects of well bore storage during pumping and aquifer afterflow to the well bore during well recovery. McWhorter's method, therefore, contains the most rigorously correct response function of the single-well methods referenced above.

A related single-hole technique is the slug withdrawal test method reported by Cooper et al. (1967) and Papadopoulos et al. (1973). In this method, well recovery is monitored following an instantaneous drawdown in the well bore. In concept, the slug test can be viewed as a drawdown/recovery test in which the pumping duration is zero and the only aquifer discharge occurring during the test is afterflow to the well bore during recovery. McWhorter considers the slug test (where pumping duration equals zero) as a limiting case to his family of solutions. Through the use of a computerized numerical integration technique, McWhorter expanded the slug test limit to include longer pumping durations and larger quantities of aquifer discharge. The numerical expansion was repeated by McWhorter up through the point at which well bore storage effects are insignificant and the simplifying assumptions inherent in the Theis Standard Recovery Test become valid. McWhorter's method, therefore, can be used to precisely analyze data from slug tests, actual pumping and recovery tests, and even from "hybrid" combinations of both.

Because of the comprehensiveness and exact analytic approach of McWhorter's method, it was selected for use in this study. The low-yield nature of the materials encountered beneath Site B justify the use of a method free from the compromising assumptions inherent in the Theis method.

Field data generated during the aquifer tests are tabulated in Appendix D. McWhorter's method requires a semilog graphical plot of  $s_w/s_o$  versus recovery time, where  $s_o$  = the draw-down in the well at the beginning of recovery, and  $s_w$  = the measured buildup in the well at each time step of recovery.  $S_w/s_o$  is plotted on the arithmetic scale, and recovery time is plotted on the logarithmic scale. Appendix D also contains the semilog plots obtained for each of the tests run. Transmissivity values are then obtained from the semilog plots by a curve-matching technique that uses a series of type curves prepared by McWhorter. A copy of McWhorter's type curves are also included in Appendix D.

#### E.4.2.3.3 Transmissivity

Transmissivity (T) data are important for characterizing the water yield aspects of an aquifer. Transmissivity is defined as the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient (Todd, 1980). Transmissivity is related to the hydraulic conductivity of an aquifer by the relationship  $T = Kb$ , where  $b$  is equal to the saturated thickness of the aquifer and  $K$  is equal to the hydraulic conductivity. Transmissivity is the principal factor determined from an aquifer test. Once transmissivity and aquifer thickness values are estimated from field tests, hydraulic conductivities and, ultimately, groundwater velocities can be determined.

The transmissivity values estimated from the 14 pumping and recovery tests are presented in Table E.4-4. These values were obtained from the semilog plots discussed above. For the most part, the semilog plots obtained from the data matched the type curves prepared by McWhorter. A notable exception occurred with Test Well D-17, for which no fit

Table E.4-4  
SUMMARY OF PRINCIPAL AQUIFER DATA

Well	Aquifer	Test <sup>a</sup> Type	Transmissivity ft <sup>2</sup> /day	Aquifer Test Section (ft)	Cumulative Sandbed Thickness (ft)	Measured Hydraulic Conductivity		Hydraulic <sup>b</sup> Gradient ft/ft	Groundwater <sup>c</sup> Velocity	
						ft/day	cm/sec		ft/day	ft/year
MW-1	Upper	R	21.0	22	5	4.20	1.5 x 10 <sup>-3</sup>	0.023	0.23	82
MW-3	Upper	R	14.0	22	4	3.50	1.2 x 10 <sup>-3</sup>	0.020	0.16	59
MW-10	Upper	P	14.0	47	5	2.80	9.9 x 10 <sup>-4</sup>	0.020	0.13	47
MW-11	Upper	P	2.1	46	3	0.70	2.5 x 10 <sup>-4</sup>	0.020	0.03	12
D-18	Upper	P	33.0	38	8	4.13	1.5 x 10 <sup>-3</sup>	0.010	0.09	33
AVERAGES			16.8	35	5	3.07	1.1 x 10 <sup>-3</sup>	0.019	0.13	47
MW-5	Lower	R	3.3	23	4	0.83	2.9 x 10 <sup>-4</sup>	0.019	0.04	13
MW-6	Lower	R	0.4	22	4	0.10	3.5 x 10 <sup>-5</sup>	0.038	0.01	3
MW-12	Lower	R	2.5	46	4	0.63	2.2 x 10 <sup>-4</sup>	0.019	0.03	10
D-17	Lower	R	No Fit, <0.1							
D-27	Lower	R	0.1	25	1	0.10	3.5 x 10 <sup>-5</sup>	0.038	0.01	2
AVERAGES			1.6	29	3	0.41	1.4 x 10 <sup>-4</sup>		0.02	7
MW-2	Span	R	4.5	26	5	0.90	3.2 x 10 <sup>-4</sup>	0.028	0.06	21
MW-4	Span	R	0.9	24	7	0.13	4.5 x 10 <sup>-5</sup>	0.019	0.01	2
MW-15	Span	P	3.3	60	8	0.41	1.5 x 10 <sup>-4</sup>	0.006	0.01	2
D-2	Span	P	10.0	50	7	1.43	5.0 x 10 <sup>-4</sup>	0.021	0.07	26
AVERAGES			4.7	40	7	0.72	2.5 x 10 <sup>-4</sup>	0.020	0.04	13

<sup>a</sup>Test Types: P = Constant rate pumping and recovery  
R = Evacuation and recovery

<sup>b</sup>Hydraulic gradients were based on the April 1985 potentiometric map

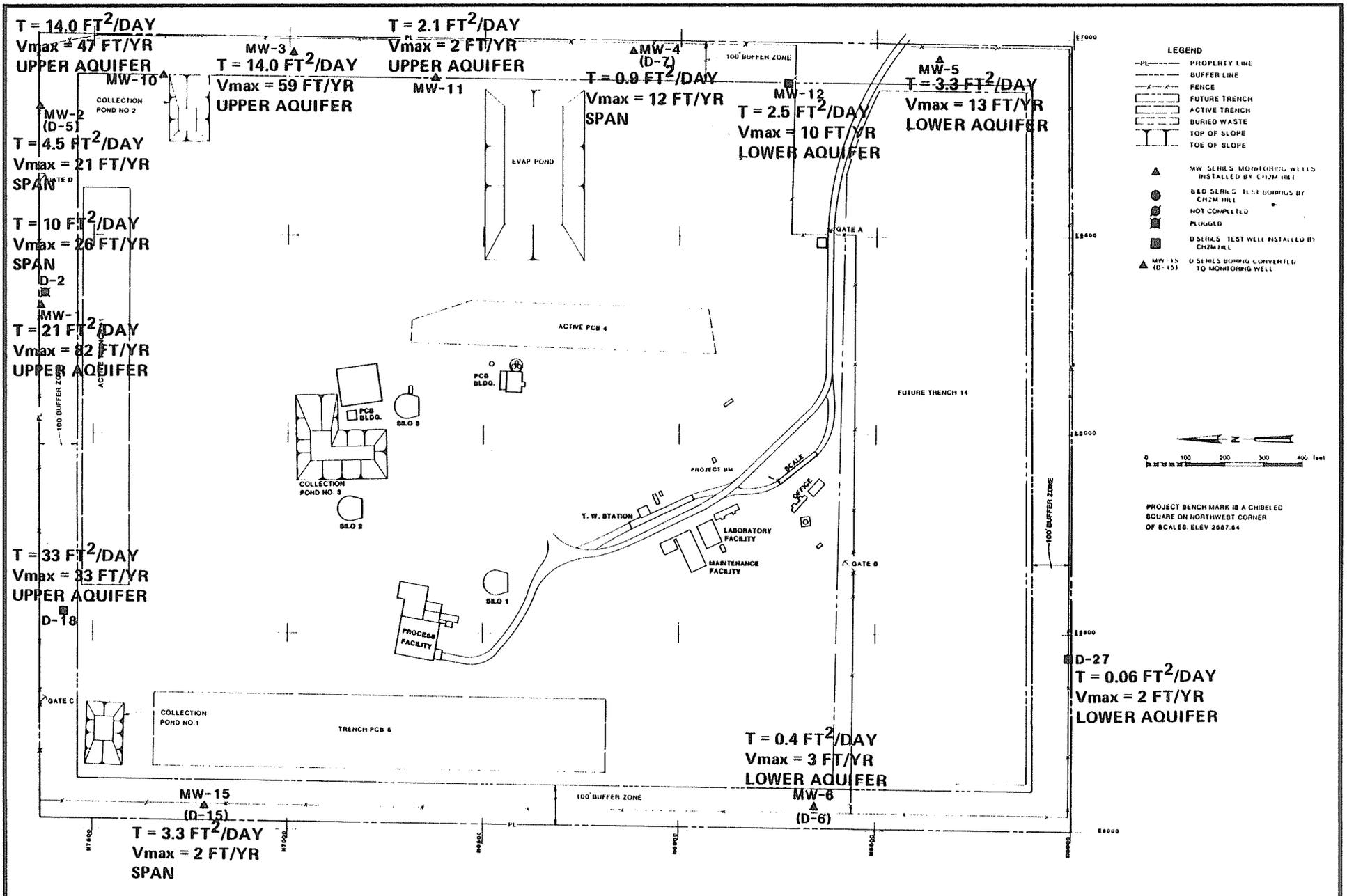
<sup>c</sup>With porosity, n = .43

could be obtained. This well experienced the slowest recovery of any of the wells tested. Even after 500 minutes of recovery time, the well had not recovered beyond the 60 percent mark, at which time the test was terminated.

The recovery response of D-17 indicated that its corresponding transmissivity would be less than that determined for any of the other test wells, because the other test wells experienced recovery much more rapidly. Hence, it can be inferred that the transmissivity at Well D-17 (lower aquifer) would be less than the lowest transmissivity obtained for any of the remaining 13 test wells. Since no transmissivity value could be calculated for Well D-17, the data could not be used to approximate groundwater velocities. The lower aquifer at D-17 can be characterized qualitatively as having a very low transmissivity ( $<0.06 \text{ ft}^2/\text{day}$ ) and consequently a very low groundwater velocity.

The transmissivity values obtained for the remaining 13 test wells ranged from a low of  $0.06 \text{ ft}^2/\text{day}$  for Well D-27 (lower aquifer) to a high of  $33 \text{ ft}^2/\text{day}$  for Well D-18 (upper aquifer). The mean transmissivity for the upper aquifer is  $16.8 \text{ ft}^2/\text{day}$ , based on an average of the five values obtained. Figure E.4-6 denotes the point transmissivity values obtained for each test site. The mean transmissivity for the lower aquifer was  $1.6 \text{ ft}^2/\text{day}$  based on four tests. The four test wells penetrating both the upper and lower aquifers gave a mean value of  $4.7 \text{ ft}^2/\text{day}$ .

To understand the significance of these transmissivity values, they can be compared to minimum values required for a domestic water supply. The U.S. Bureau of Reclamation has investigated and published the transmissivity values necessary for water supply development purposes (USBR, 1977). Transmissivity values below one  $\text{ft}^2/\text{day}$  are considered infeasible



**FIGURE E.4-6**  
**POINT TRANSMISSIVITY AND**  
**MAXIMUM POINT VELOCITY VALUES**



for domestic well purposes, while transmissivity values between one  $\text{ft}^2/\text{day}$  and  $10 \text{ ft}^2/\text{day}$  are considered poor. Fair well potential can be achieved with transmissivity values between 10 and  $100 \text{ ft}^2/\text{day}$ . Thus, the transmissivity values obtained for the test sites are generally in the infeasible to poor well potential range, with only four of the 13 values falling in the low end of the fair range.

#### E.4.2.3.4 Hydraulic Conductivity

Hydraulic conductivity (K) values can be obtained from the above transmissivity data through the relationship  $K = T/b$ , where  $b$  = the saturated aquifer thickness. Representative thickness values were obtained for 13 of the 14 single-hole test wells (where successful transmissivity values were obtained) via an interpretation of subsurface conditions at each respective test site. Information from all geologic and geophysical logs and geologic data from the cores at D-21, D-22, and D-23 were used to estimate the actual thickness of sandbeds present within each test interval. This was done to adjust the aquifer test results under the premise that most of the aquifer response during the tests occurs from the sandier aquifer zones, and not the adjacent confining zones, a portion of which is generally included in the test interval. This resulted in a conservative reduction in the thickness values and an associated conservative increase in hydraulic conductivities.

Table E.4-4 shows that the calculated conductivity values for the lower aquifer materials range from a minimum of  $3.5 \times 10^{-5}$  cm/sec at Wells MW-6 and D-27 to a maximum of  $2.9 \times 10^{-4}$  cm/sec at Well MW-5. The upper aquifer materials range from a minimum of  $2.5 \times 10^{-4}$  cm/sec at MW-11 to a maximum of  $1.5 \times 10^{-3}$  cm/sec at Wells MW-1 and D-18.

These values are representative of very fine sands and mixtures of sand, silt, and clay, which are reported to have conductivity values ranging from  $10^{-3}$  cm/sec to  $10^{-6}$  cm/sec (Todd, 1980). Consistent results were observed between the geologic classification of subsurface materials and their calculated conductivity values.

#### E.4.2.3.5 Supplemental Hydraulic Conductivity Data

Packer Tests. Six boreholes were pressure-tested at the site during early exploratory drilling efforts. A pneumatic wireline packer assembly was used to perform the tests with inflow pressures ranging from 10 to 50 psi. The boreholes tested were D-2, D-3, D-4, D-8, D-9, and D-10. Twenty-three discrete intervals were tested. These tests were conducted between September 1983 and June 1984.

The packer tests were used to help identify the location of water-bearing zones during the initial stages of the investigative program and, as a result, provided some reconnaissance-level information on hydraulic conductivity values in the subsurface. Table E.4-5 summarizes the intervals tested in each borehole and presents the observed hydraulic conductivity values that were obtained.

The packer tests provided approximate values of hydraulic conductivity, which were useful for initial planning purposes. When compared to the conductivity data obtained from the pumping and recovery tests, the packer tests generally yielded conductivity values two to three orders of magnitude lower than those obtained from the pump tests. Reasonable explanations for this finding are that the packer test intervals did not always correspond to the sandbeds and that the conductivities obtained from the pump tests were corrected for the saturated thickness of the sandier (aquifer) zones,

Table E.4-5  
PACKER TEST SUMMARY  
ESII SITE B

<u>Well No.</u>	<u>Date</u>	<u>Test Interval (ft below ground level)</u>	<u>K (cm/sec)</u>	<u>Inflow Pressure (psi)</u>	<u>Comments</u>
D-2	09/28/83	306-326	$7.0 \times 10^{-7}$	15.5	
			$1.0 \times 10^{-6}$	30.0	
			$1.1 \times 10^{-6}$	50.0	
D-2	09/29/83	326-357	$2.0 \times 10^{-7}$	15.0	
			$2.7 \times 10^{-7}$	30.0	
			$4.6 \times 10^{-7}$	50.0	
D-2	09/30/83	357-392	$8.0 \times 10^{-8}$	15.0	
			$3.5 \times 10^{-7}$	30.0	
			$3.5 \times 10^{-7}$	50.0	
D-2	10/03/83	391-430	$1.1 \times 10^{-7}$	15.0	
			$1.6 \times 10^{-7}$	30.0	
			$1.9 \times 10^{-7}$	50.0	
D-2	10/03/83	303-430	$1.8 \times 10^{-6}$	15.0	
			$2.1 \times 10^{-6}$	30.0	
			$2.5 \times 10^{-6}$	45.0	
D-3	04/18/84	345-368	$1.1 \times 10^{-5}$	14.0	
			$1.5 \times 10^{-5}$	30.0	
			$1.9 \times 10^{-5}$	45.0	
D-3	04/19/84	375-407	$1.5 \times 10^{-7}$	16.0	
			$7.0 \times 10^{-8}$	30.0	
			$1.7 \times 10^{-7}$	50.0	
D-4	05/10/84	263-292	$6.3 \times 10^{-7}$	12.5	
			$4.1 \times 10^{-7}$	30.0	
			$6.8 \times 10^{-7}$	47.0	
D-4	05/11/84	300-334	$2.2 \times 10^{-7}$	11.0	
			$3.4 \times 10^{-7}$	30.0	
			$7.1 \times 10^{-7}$	48.5	
D-4	05/12/84	332.5-372.5	$3.8 \times 10^{-7}$	11.5	
			$2.3 \times 10^{-7}$	30.0	
			$1.3 \times 10^{-7}$	49.5	
D-4	05/15/84	384.5-400.5	$4.1 \times 10^{-7}$	10.0	
			$6.3 \times 10^{-7}$	30.0	
			$5.2 \times 10^{-7}$	48.0	
D-8	05/18/84	210-245	$2.4 \times 10^{-7}$	10.5	
			$2.2 \times 10^{-7}$	31.0	
			$2.2 \times 10^{-7}$	49.5	

Table E.4-5 (continued)  
 PACKER TEST SUMMARY  
 ESII SITE B

Well No.	Date	Test Interval (ft below ground level)	K (cm/sec)	Inflow Pressure (psi)	Comments
D-8	05/18/84	265-300	$8.4 \times 10^{-7}$	10.0	
			$8.8 \times 10^{-7}$	31.0	
			$9.0 \times 10^{-7}$	46.5	
D-8	05/19/84	304.5-347	$6.5 \times 10^{-7}$	9.0	
			$7.1 \times 10^{-7}$	30.0	
			$7.1 \times 10^{-7}$	48.0	
D-8	05/21/84	365-400	$4.3 \times 10^{-7}$	9.0	
			$3.5 \times 10^{-7}$	30.0	
			$4.7 \times 10^{-7}$	48.5	
D-9	05/23/84	205-237	-	11.0	No Take
			-	30.0	No Take
			$1.2 \times 10^{-7}$	49.0	
D-9	05/24/84	265-288.5	$2.2 \times 10^{-7}$	11.0	
			$5.4 \times 10^{-7}$	30.0	
			$4.7 \times 10^{-7}$	49.0	
D-9	05/24/84	310-340	-	10.0	No Take
			$1.5 \times 10^{-7}$	30.0	
			$1.3 \times 10^{-7}$	48.0	
D-9	05/29/84	370-401.5	-	12.0	No Take
			-	30.0	No Take
			-	44.0	No Take
D-10	05/31/84	195-243	-	10.5	No Take
			$3.1 \times 10^{-6}$	30.0	
			$2.9 \times 10^{-6}$	48.0	
D-10	06/01/84	265-304.0	-	10.0	No Take
			$1.5 \times 10^{-6}$	30.0	
			$1.4 \times 10^{-6}$	48.0	
D-10	06/02/84	310-345	-	-	Erratic Inflow Pressure
			$6.9 \times 10^{-8}$	30	
			$2.9 \times 10^{-7}$	48	
D-10	06/02/84	365-401.5	$3.1 \times 10^{-7}$	10.5	
			$1.3 \times 10^{-7}$	30.0	
			$1.7 \times 10^{-7}$	47.0	

while the packer tests in most cases included both the sandier zones and the finer-grained aquiclude zones. The aquiclude zones would be expected to exhibit lower conductivities by a factor of at least two orders of magnitude, based on observations of the subsurface materials encountered. It may be inferred that the packer tests provided a conservative estimate of the conductivities that may be expected for the aquicludes. The values in the  $10^{-7}$  cm/sec and  $10^{-8}$  cm/sec range are characteristic of unweathered clays, and those in the  $10^{-6}$  range are characteristic of silt and clay mixtures (Todd, 1980).

Because the measurement data obtained from the pumping tests were considered more precise and also yielded higher (more conservative) conductivity values, only the conductivities obtained from the pump tests were used in the velocity computations presented in Section E.4.2.4.2.

Grain-Size Technique. As a supplement to the in situ determination of hydraulic conductivity provided by the aquifer tests, hydraulic conductivity values were also calculated by the Hazen method. The Hazen method is one of several predictive equations that relate hydraulic conductivity values to the grain-size distribution of representative aquifer materials. These equations allow for an estimation of hydraulic conductivity in situations where direct permeability data are sparse, such as in early aquifer exploration studies or where an independent check of hydraulic conductivity obtained through other means is desired. The techniques are approximation methods, but generally provide useful estimates of hydraulic conductivity (Freeze and Cherry, 1979). Todd (1980) cautions that the empirical formulas may not give reliable results because of the difficulty of including all possible variables in porous media. Therefore, field and laboratory methods are preferable as a general rule.

The Hazen method estimates K through the following relationship:

$$K = A(d_{10})^2$$

Where:

- K = hydraulic conductivity
- A = a conversion factor [equal to 1.0 when K is reported in cm/sec and grain size in millimeters (mm)]
- $d_{10}$  = grain-size diameter at which 10 percent by weight of the particles are finer

Grain size and hydrometer analyses were performed on 85 samples of materials representing both upper and lower aquifers, which were recovered from a total of nine borings at the ESII site. Grain-size distribution curves were prepared from these data. Appendix A contains the results of the grain-size analyses and six composite grain-size curves prepared for samples from Borings D-1, D-3, D-4, D-8, D-9, and D-10. Each curve presents in composite form the range of values observed for the entire suite of samples analyzed for each particular borehole. Additional grain-size analyses were performed on portions of the core retrieved from Test Holes D-21, D-22, and D-23. These data are also provided in Appendix A, but individual plots instead of composite curves are provided.

Maximum  $d_{10}$  values were selected from the grain-size distribution curves for each of the nine boreholes. Maximum values (rather than minimum values of  $d_{10}$ ) were selected since this would be more representative of the water-bearing sandbeds within the aquifer. Many minimum  $d_{10}$  values are below 0.0001; thus, by this method the clays within the aquifers have hydraulic conductivities of less than  $10^{-8}$  cm/sec. Maximum

$d_{10}$  values were then entered into the Hazen formula and the empirical hydraulic conductivity values were calculated. Table E.4-6 lists the values of conductivity determined in this manner for each of the nine boreholes.

From Table E.4-6 it can be seen that the range of empirically derived K values are somewhat lower than those determined with the pump tests. As with the packer tests, the K values obtained from the grain-size analyses may include materials from the aquiclude zones that are adjacent to the sandier aquifer zones. This could account for the somewhat lower values observed. The mean empirically derived hydraulic conductivity value of  $3.4 \times 10^{-5}$  cm/sec does, however, fall within the range of values obtained from the pump tests, indicating that the empirical data do function as a useful independent check of the pump test data.

As with the packer test data, the hydraulic conductivity values obtained from the grain-size analyses were not used in the computation of groundwater velocities. Rather, they have been included for exemplary purposes and as an additional check on pumping test-derived hydraulic conductivities.

#### E.4.2.3.6 Storage Coefficient

Single-hole aquifer tests do not allow for a reliable calculation of the aquifer storage coefficient, as stated by Cooper et al. (1967) and Kruseman and deRidder (1970). Therefore, the aquifer storage coefficient was estimated from published information. Freeze and Cherry (1979) report storage values of  $10^{-5}$  to  $10^{-3}$  for confined aquifers. McWhorter (1981) bases his single-hole method for confined aquifers on a storage coefficient of  $10^{-4}$ . Todd (1980) reports storage coefficients for confined aquifers as ranging from  $10^{-5}$  to  $10^{-3}$ . Lohman (1972) presents a rule-of-thumb

Table E.4-6  
EMPIRICAL HYDRAULIC CONDUCTIVITY VALUES

Borehole	Total Number of Samples Analyzed	Maximum Reported $d_{10}$ Value	Hydraulic Conductivity <sup>a</sup>
D-1	4	0.005	$2.5 \times 10^{-5}$
D-3	7	0.002	$4.0 \times 10^{-6}$
D-4	9	0.0035	$1.2 \times 10^{-5}$
D-8	8	0.0025	$6.3 \times 10^{-6}$
D-9	10	0.002	$4.0 \times 10^{-6}$
D-10	9	0.005	$2.5 \times 10^{-5}$
D-21	12	0.003 (projection)	$9 \times 10^{-6}$
D-22	17	0.005	$2.5 \times 10^{-5}$
D-23	9	0.014	<u><math>2.0 \times 10^{-4}</math></u>
Arithmetic Mean =			$3.4 \times 10^{-5}$

<sup>a</sup>Calculated using the Hazen Formula (after Freeze and Cherry, 1979).

relationship for estimating storage coefficient for confined aquifers as:

$$s = 10^{-5}b$$

Where:

S = storage coefficient

b = aquifer thickness in feet

Using this relationship, aquifer storage coefficients at the ESII site were estimated to range from  $3 \times 10^{-5}$  to  $1.8 \times 10^{-4}$ , based on calculated saturated aquifer thicknesses of 3 feet to 8 feet. These values fall into the range reported by Todd (1980) and Freeze and Cherry (1979), and are, therefore, considered representative.

The aquifer storage coefficient has merit in the characterization of groundwater systems for water supply development; however, it is not a necessary factor in the determination of groundwater velocities and direction of flow.

#### E.4.2.3.7 Barometric Efficiency

The barometric efficiency of an aquifer is a measure of the response of water levels in wells set in confined aquifers to changes in barometric pressure. It is expressed as the ratio of the change in water level to the change in barometric pressure (both expressed in the same units), and ranges from zero to one. An increase in barometric pressure results in a decrease in water levels, and vice versa. The evaluation of the barometric efficiency of an aquifer provides two important pieces of information. First, the numerical value of the barometric efficiency can be used to "correct" measured water levels to eliminate the effects of barometric pressure

changes. Second, the magnitude of the barometric efficiency indicates the extent to which an aquifer is confined; a strongly confined aquifer has a high barometric efficiency.

To evaluate the barometric efficiency of the aquifer beneath the ESII Site B, continuous water-level data were collected using Stevens Type F water-level recorders. Recorders were installed on MW-9 and MW-11 (upper aquifer wells) and MW-12 (lower aquifer well) in mid-September 1984, and records were obtained through the first week of December 1984. Recorder charts are provided in Appendix E. There are some gaps in the records as a result of equipment malfunction and disruptions resulting from water sampling. The barometric pressure at the site was continuously recorded from September 27, 1984, through December 6, 1984. The barometric pressure and water-level data are shown on Figure E.4-7. The water levels are presented as the depth to water in the well measured from the surface. Thus, an increase in the "depth to water" represents a decrease in water level.

The data presented on Figure E.4-7 show a strong correlation between barometric pressure changes and water-level changes in MW-9 and MW-11, particularly during the latter half of the record. The water-level data for MW-12 show only a slight response to barometric pressure changes.

The change in barometric pressure and the corresponding change in water levels are tabulated in Table E.4-7, along with the barometric efficiency computed for each occurrence of a barometric pressure change. The arithmetic averages of the barometric efficiencies computed for each well are also given in Table E.4-7.

The conclusion drawn from evaluating barometric efficiencies is that the upper aquifer beneath the ESII Site B is a confined aquifer in the areas near MW-9 and MW-11, and the lower

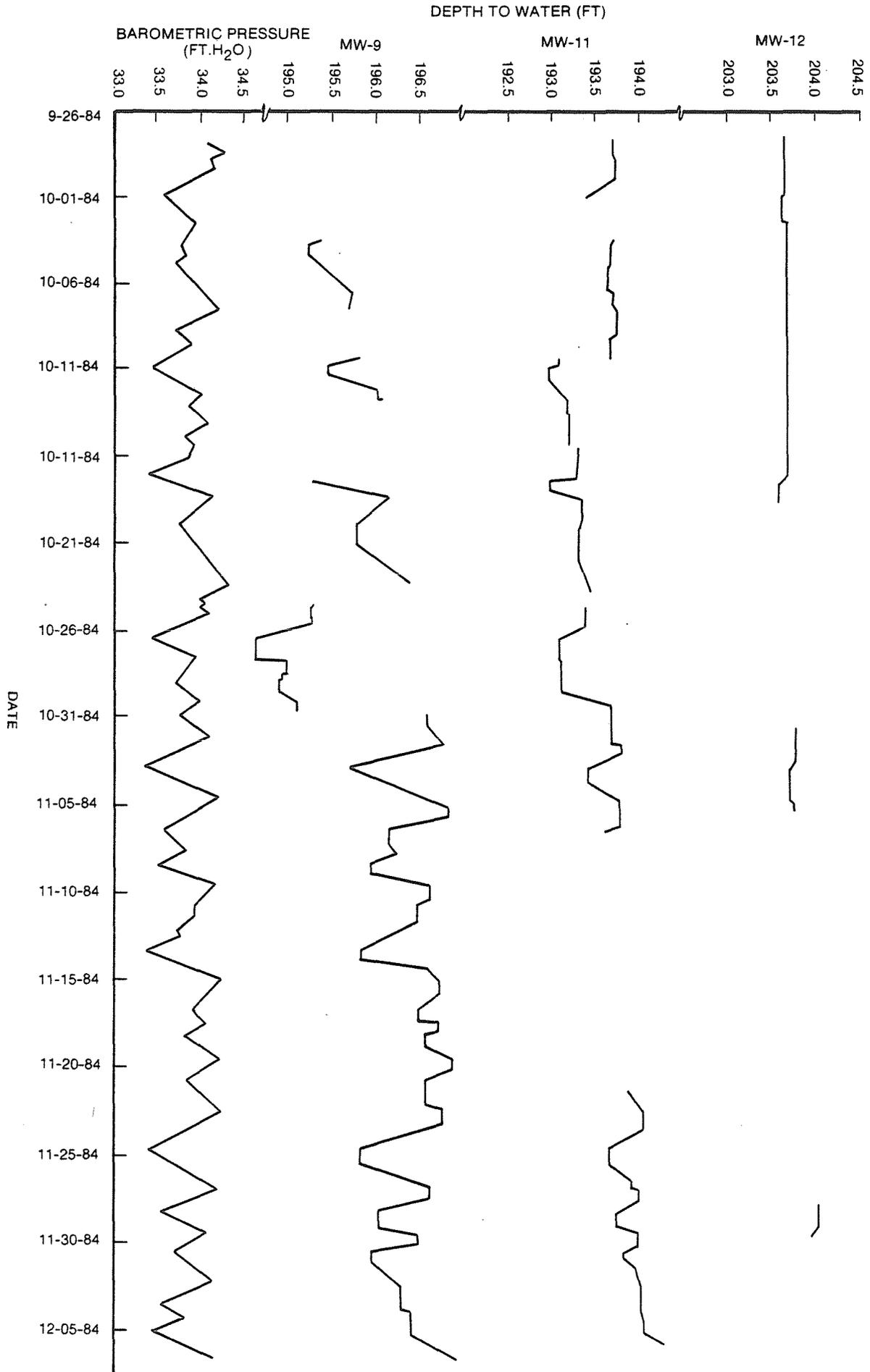


FIGURE E.47  
WATER LEVEL AND  
BAROMETRIC PRESSURE CHANGES



Table E.4-7  
BAROMETRIC EFFICIENCIES

Date	Time	Barometric Pressure Change (ft H <sub>2</sub> O)	Water Level Change (ft)			Barometric Efficiency		
			MW-9	MW-11	MW-12	MW-9	MW-11	MW-12
07-27-84	1900	0						
09-28-84	1100	0.20						
	2000	-0.17						
09-29-84	1000	0.06						
09-30-84	2400	-0.56		0.33			0.59	
10-02-84	1200	0.34						
10-03-84	1000	0.06						
	2000	-0.11		0.04			0.36	
10-07-84	1200	0.48	-0.44	-0.13		0.92	0.27	
10-08-84	1700	-0.47		0.01				
10-09-84	1200	0.16						
10-10-84	2100	-0.43						
10-12-84	1000	0.55	-0.59			1.07		
10-13-84	0300	-0.14						
	2400	0.21						
10-14-84	2100	-0.26						
10-15-84	0900	0.11						
	2400	-0.06						
10-16-84	2400	-0.50						
10-18-84	0600	0.74	-0.87			1.18		
10-19-84	1800	-0.36	0.36			1.00		
10-23-84	0600	0.54	-0.61			1.13		
10-24-84	0200	-0.32						
	1000	0.06						
	1500	-0.06						
	2400	0.09						
10-26-84	1000	-0.64	0.64	0.30		1.00	0.47	
10-27-84	1200	0.50	-0.35			0.70		
10-28-84	2200	-0.21	0.07			0.33	0.30	
10-29-84	2400	0.27	-0.19	-0.08		0.70		
10-30-84	1800	-0.23	0.08			0.35		
10-31-84	2400	0.34	-0.18			0.53		
11-02-84	1400	-0.73	1.03	0.35	0.06	1.41	0.48	0.082
11-04-84	1200	0.82	-1.11	-0.35	-0.03	1.35	0.43	0.036
11-06-84	0700	-0.61	0.67			1.10		
11-07-84	1200	0.24	-0.09			0.38		
11-08-84	0900	-0.33	0.32			0.97		
11-09-84	1200	0.67	-0.68			1.01		
11-10-84	1600	-0.25	0.13			0.52		
11-11-84	0600	0.02	0			0		
11-12-84	0400	-0.23	0.25			1.09		
	1100	0.06						
11-13-84	0500	-0.40	0.41			1.02		
11-14-84	2200	0.87	-0.91			1.04		

Table E.4-7 (continued)  
 BAROMETRIC EFFICIENCIES

Date	Time	Barometric Pressure Change (ft H <sub>2</sub> )	Water Level Change (ft)			Barometric Efficiency		
			MW-9	MW-11	MW-12	MW-9	MW-11	MW-12
11-16-84	1500	-0.34	0.23			0.68		
11-17-84	1100	0.15						
11-18-84	0200	-0.23	0.16			0.70		
11-19-84	1200	0.37	-0.30			0.81		
11-20-84	1600	-0.35	0.29			0.83		
11-22-84	1100	0.37	-0.17			0.46		
11-24-84	1400	0.81	-0.94		0.37	1.16	0.46	
11-26-84	2200	0.78	-0.80		-0.31	1.02	0.40	
11-28-84	0400	-0.64	0.59		0.24	0.92	0.38	
11-29-84	1000	0.48	-0.30			0.62		
11-30-84	1200	-0.35	0.53		0.17	1.51	0.48	
12-02-84	0400	0.44	-0.34		-0.17	0.77	0.39	
12-03-84	1200	-0.58						
12-04-84	0500	0.25	-0.10		-0.04	0.40	0.16	
	2400	0.35						
12-06-84	1200	0.67	-0.53		-0.23	0.79	0.34	
AVERAGE						0.84	0.39	0.059

BOT420/D.201

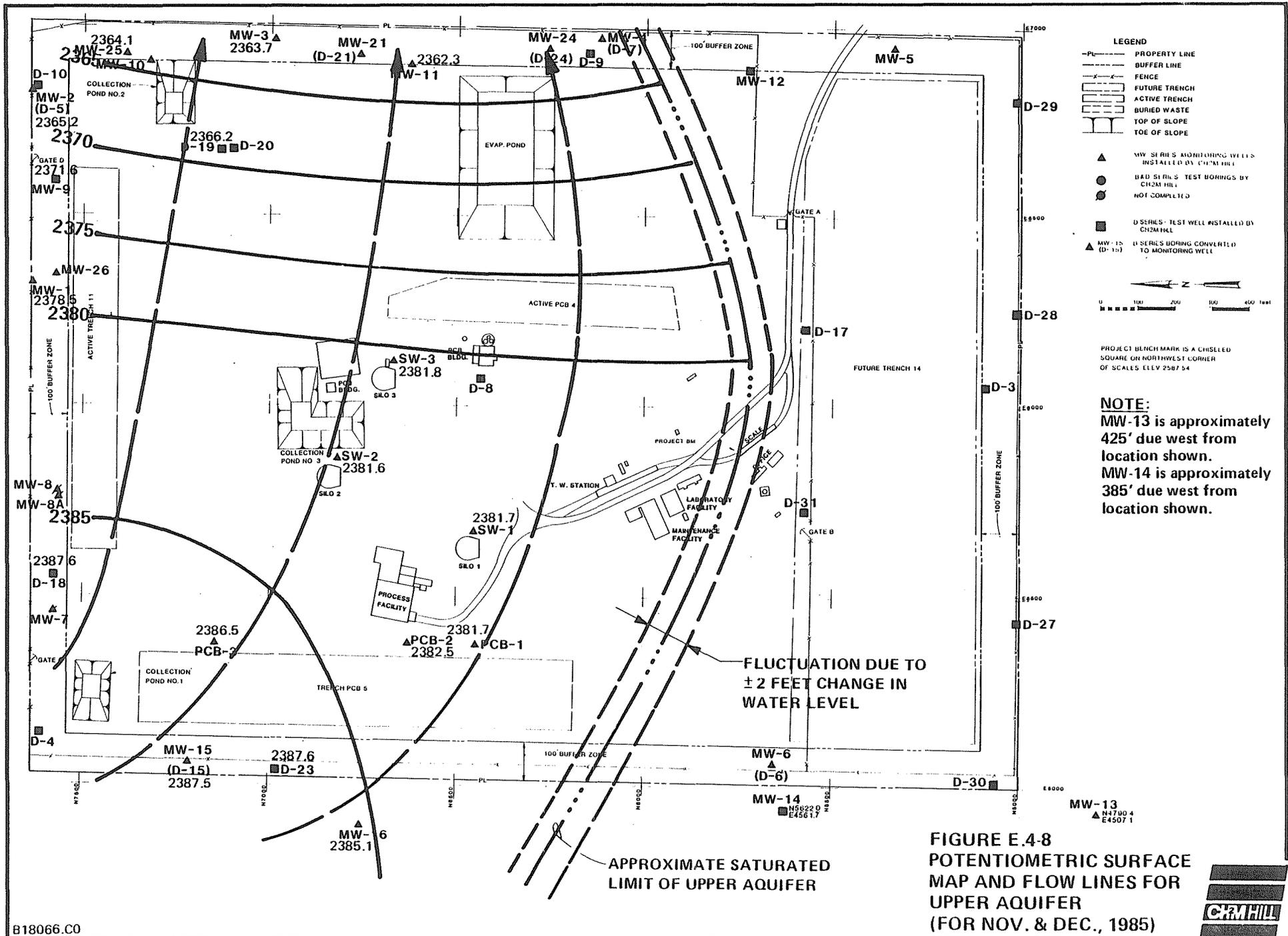
⊖  
aquifer is unconfined near MW-12. However, the geologic data obtained from Corehole D-22 adjacent to MW-12 indicate the lower aquifer is also confined. The limited response to barometric pressure observed at MW-12 suggests the aquifer here is very poorly developed (very low yielding and sluggish responses to pressure changes), or the well construction at MW-12 did not allow accurate observations of water-level fluctuations.

#### E.4.2.4 GROUNDWATER FLOW DIRECTION AND RATE

##### E.4.2.4.1 Water Level and Hydraulic Gradient Data

*Review with new WL Data gradients & flow by*  
⊖  
To facilitate meeting the requirements of 40 CFR 270.14(c)(2), groundwater levels at the ESII Site B have been measured periodically in all monitoring wells, test wells, and piezometers installed during the site characterization investigation. Water levels have been measured monthly at 21 wells. Water levels for the upper aquifer, lower aquifer, and for the clays above and below the lower aquifer have been obtained. Water-level data through December 31, 1985, are included in Appendix E. Continuous water-level data were recorded at MW-9, MW-11, and MW-12 for a period of about 2 months, from October to December 1984.

*add 86 new maps & WL*  
⊖  
Potentiometric Surface. Potentiometric surface maps have been constructed for the upper and lower aquifers. Potentiometric surface maps using water-level data from November and December 1985 are provided as Figures E.4-8 and E.4-9. Potentiometric surface maps for other dates are provided in Appendix E. The equipotential lines were drawn by interpolating between measured water levels. Only those wells specific to the particular aquifer were used to construct the potentiometric surface maps. Pursuant to 40 CFR 270.14(c)(2), flow lines, which indicate the horizontal direction of flow across



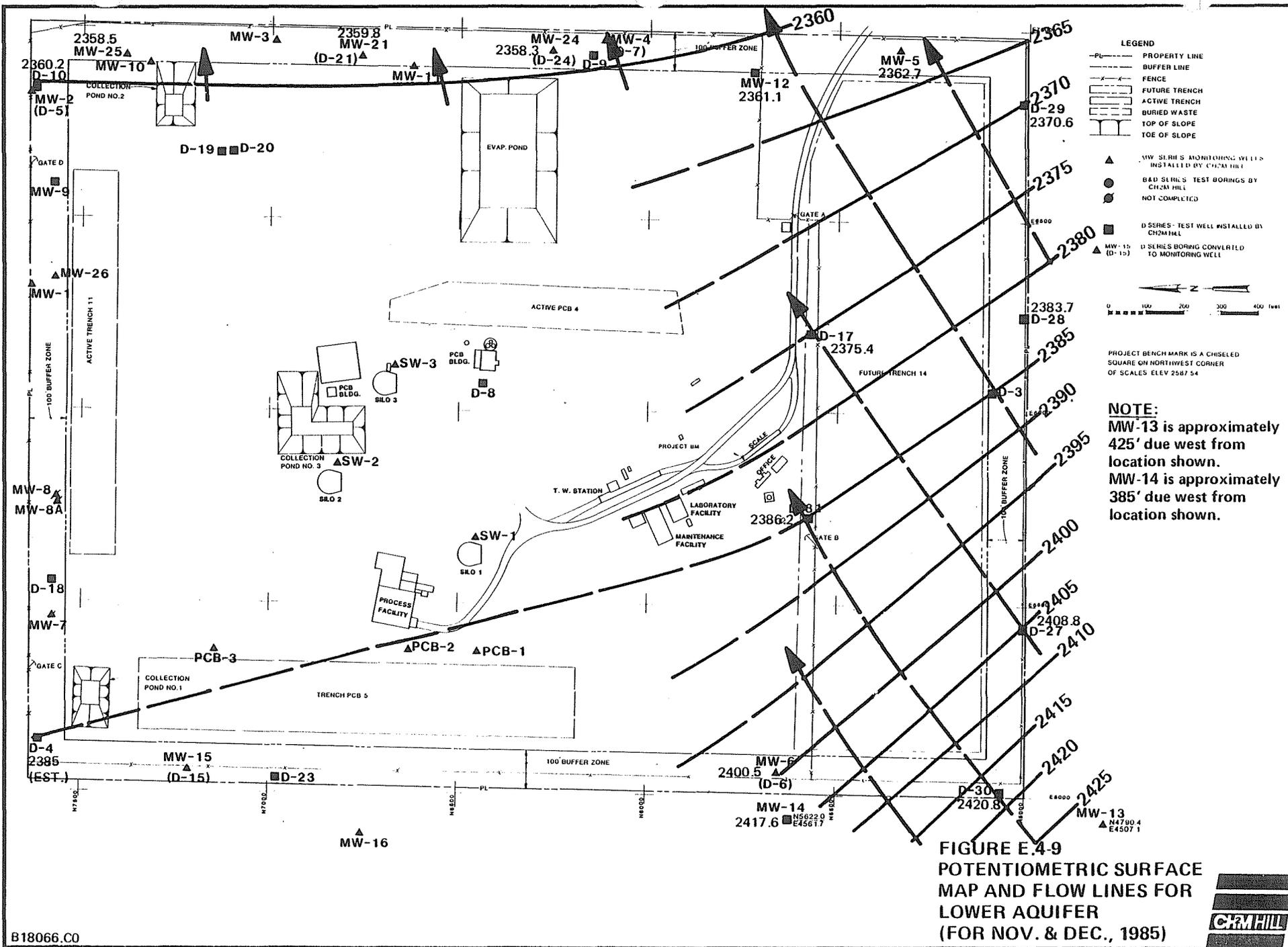
- LEGEND**
- PL — PROPERTY LINE
  - - - - - BUFFER LINE
  - FENCE
  - FUTURE TRENCH
  - ACTIVE TRENCH
  - BURIED WASTE
  - TOP OF SLOPE
  - TOE OF SLOPE

- ▲ MW SERIES MONITORING WELLS INSTALLED BY CH2M HILL
  - BAD SERIES TEST BORINGS BY CH2M HILL NOT COMPLETED
  - D SERIES TEST WELL INSTALLED BY CH2M HILL
  - ▲ MW-15 (D-15) D SERIES BORING CONVERTED TO MONITORING WELL
- 0 100 200 300 400 feet

PROJECT BENCHMARK IS A CHISELED SQUARE ON NORTHWEST CORNER OF SCALE'S ELEV 2587.54

**NOTE:**  
 MW-13 is approximately 425' due west from location shown.  
 MW-14 is approximately 385' due west from location shown.





the site, were drawn perpendicular to the equipotential lines. Tabulated water-level data and hydrographs for all wells showing the time variation in water levels are provided in Appendix E. As shown by these data, month-to-month water-level fluctuations are small, less than 2 feet. The water-level data also indicate that in some wells it took as much as 1.2 years (MW-2) for water levels to stabilize after the disruption of well installation, development, and sampling. Slow stabilization is directly related to the low yields of the aquifers.

Horizontal Gradients (Upper Aquifer). As shown on Figure E.4-8, water in the upper aquifer is entering the site from the northwest corner and generally moves to the east. Water appears to be entering the site along the entire northern boundary of the site based on flow lines shown on Figure E.4-8.

Gradients are fairly consistent across the northeastern quarter of the site, where they range from 0.02 to 0.03 feet/feet. In the northwest corner of the site, gradients are much lower. This reflects the higher transmissivity of the upper aquifer in this area, which results from the presence of more extensive sandbeds. From the northwest corner to the north-central portion of the site the gradients range from 0.006 to 0.01 feet/feet.

The southern lateral limit of the upper aquifer is defined by the intersection of the aquifer's potentiometric surface and the top of the inner clay that separates the upper and lower aquifers. South of this lateral limit, the upper aquifer is no longer saturated. While there are no wells that explicitly define this boundary, the additional data gained from Well D-31 and Corehole D-32 have allowed refinement of the location of the projected boundary (see

Figure E.4-8). In addition to the projected aquifer boundary, the estimated range of fluctuation that might occur in the boundary is shown. This range is based on a 2-foot potentiometric fluctuation and a 2- to 4-degree geologic dip of the aquifer sands. If only the sandbeds are used to define the significant water-bearing portions of the aquifer, the southern limit of the "aquifer" may be as much as 300 feet north of the line shown. This is based on the dip and the height of the first sand above the confining clay (13 feet) in Corehole D-32.

Water in the upper aquifer in the northwest corner of the site is moving along strike (approximately northwest to southeast). The core logs from D-21, D-22, D-23, and D-32 indicate the sandbeds of the upper aquifer may pinch or thin to the north of the site. This is consistent with the near-shore depositional environment thought to be responsible for the existence of the sand seams of the upper and lower aquifers at the site. It has been noted by other geologists familiar with the Glenns Ferry that sandbeds demonstrate more lateral consistency along strike than up- or downdip. Thus, the aquifers may not only be confined vertically but also laterally. This lateral confinement would force groundwater to flow parallel to strike away from the apparent recharge to the northwest. The flow direction may be the result of infiltration from irrigation to the northwest and from Castle Creek lying west of the site.

Horizontal Gradients (Lower Aquifer). Groundwater in the lower aquifer moves in a fairly uniform pattern along the southern portion of the site (see Figure E.4-9). Gradients are highest in the southwest corner of the site, between MW-6 and MW-13, where they are 0.04 foot/foot. From MW-6 to D-24 along the southeast side of the site, the gradients flatten out to 0.02 foot/foot and follow a more easterly direction.

This change in gradients apparently corresponds to the lateral transition (southwest to northeast) of the lower aquifer material from less sandy to more extensively developed sandbeds. Higher gradients are present where the aquifer is less able to conduct water. Water in the lower aquifer south of the site is moving downdip, following the trend of the sandbeds. Along the northeastern side, the lower aquifer sandbeds become more pronounced and more permeable; thus, the gradients flatten out in response to this increased water-bearing capability (relatively speaking). The water-level data indicate gradients in the lower aquifer parallel the easterly flow of the upper aquifer. This flow direction also parallels the general strike of the beds, and it is probable that the lower aquifer sands also pinch out farther to the north. As is apparent from Figure E.4-9, there is not much data available on the potentiometric surface of the lower aquifer in the center of the site. Aquifer bed and confining clay continuity within the lower aquifer was demonstrated from deep coreholes and wells along the perimeter. Potentiometric surface data were projected across the northwestern portion of the site on the basis of observed water-level differences between the upper and lower aquifers elsewhere on the site.

Vertical Gradients. Vertical gradients between the upper and lower aquifers have been measured at several locations where an upper and lower well pair were installed. Additional insight into the head relationships between the upper and lower aquifers can be obtained by superimposing the potentiometric surface maps for the two aquifers.

Downward gradients are present over most, if not all, of the area where the upper aquifer is saturated. Water levels in the upper aquifer are 3 to 6 feet higher than water levels in the lower aquifer, as measured at Wells D-21s/D-21d and

D-10s/D-10d, respectively. In the extreme northwest corner and in the central portion of the site where the upper aquifer becomes unsaturated, water levels in the two aquifers are the most alike. They become increasingly separated to the north and northeast as more of the upper aquifer becomes saturated.

Comparison of water levels between the clay beneath the lower aquifer and for the lower aquifer at Wells D-9d and D-24 indicates an upward gradient of 1.4 feet over 45 feet is present. Upward gradients developing with depth are consistent with regional hydrological flow patterns.

The downward gradients present between the upper and lower aquifers are a reflection of the source (direction) of recharge, relative hydraulic conductivities of the aquifers, and the tight confining clay separating them. Testing has indicated the inner confining clay separating the two aquifers has vertical permeabilities of  $10^{-6}$  to  $10^{-8}$  cm/sec and that no hydraulic connection exists between the two aquifers because the upper portions of the inner clay are not fully saturated (Table E.4-2). Since no vertical flow is occurring, the head differences may be attributed to the higher hydraulic conductivities and transmissivity of the upper aquifer in the northwest corner, which are allowing the higher upgradient heads to be more easily distributed farther downgradient. In this flow system, this results in water levels 3 to 6 feet higher in the upper aquifer than in the lower aquifer. Regionally upward gradients predominate.

Temperature Profiling. Detailed temperature profiles in wells that have been allowed to reach static equilibrium following drilling, sampling, or testing may reveal water flow zones within the aquifer. On January 8 and 9, 1985, high resolution static temperature logs were run in most of the wells not equipped with permanently installed pumps.

Monitoring Wells MW-1, MW-2, MW-3, MW-5, and MW-6 were not logged because of concerns about contaminating or cross contaminating the established monitoring wells with the logging tools or cable.

The logging equipment was modified by the contractor to obtain approximately 4 inches of lateral recorder pen movement representing about 2°C actual temperature fluctuation. In addition, a digital recording of tool response was obtained every two-tenths of a foot. All holes were logged at 3 feet per minute on one pass down the hole. Logging was started 10 to 20 feet above static water level and continued into the silt sump beneath the well screen. Copies of the recorder charts are provided in Appendix C.

Discrete zones of moving groundwater were not indicated by the logs. All wells exhibited the same basic pattern of temperature distribution, although the log trace was slightly different for each well.

#### E.4.2.4.2 Groundwater Velocity

Pursuant to 40 CFR 270.14(c)(2), the determination of representative groundwater velocities was accomplished by applying the Darcy flow equation to the hydrogeologic conditions observed at the project site. The Darcy equation provides for the calculation of groundwater velocities using the following relationship:

$$\text{Groundwater Velocity} = \frac{KI}{n_e}$$

Where:

K = hydraulic conductivity of the aquifer

I = hydraulic gradient in the aquifer

$n_e$  = effective porosity of the aquifer material

To successfully determine groundwater velocity, each term in the Darcy flow equation must be accurately defined from representative field data. The sections below review how each of the terms in the velocity equation were evaluated at the site.

Hydraulic Conductivity. The K values used in the equation were those obtained from the single-hole pump tests performed at the site. The values observed (as reported in an earlier section) ranged from  $3.5 \times 10^{-5}$  cm/sec to  $2.9 \times 10^{-4}$  cm/sec for the lower aquifer, and from  $2.5 \times 10^{-4}$  cm/sec to  $1.5 \times 10^{-3}$  cm/sec for the upper aquifer.

Aquifer Porosity. The porosities of the aquifer materials were determined in the laboratory. The aquifer materials of interest, as identified from geologic and geophysical logging activities, consist of fine silty sands and sandy silts. Freeze and Cherry (1979) report porosity values of 0.25 to 0.50 for sands, and 0.35 to 0.50 for silts. Powers (1981) lists typical porosity values of 0.30 for dense graded sands and 0.40 for loose graded sands. Bouwer (1978) lists the porosity of fine sands at 0.40 to 0.50. These values support the representativeness of the laboratory values presented below.

Porosities determined from the lab testing on the upper and lower aquifer portions of Coreholes D-21, D-22, and D-23 ranged from 0.43 to 0.46, and averaged 0.44. These values are for eight undisturbed core samples that were tested. The test results are summarized in Table E.4-2.

The actual porosity and the effective porosity of the aquifer materials were considered equivalent, on the basis of the following references. Todd (1980) suggests that for most unconsolidated porous media, the porosity and the effective

porosity are generally the same. Freeze and Cherry (1979) state that for most granular media, approximating effective porosity ( $n_e$ ) by actual porosity ( $n$ ) introduces little error. On the basis of these recommendations, the measured porosity is considered to also represent the effective porosity.

Given the relationship of porosity to the Darcy velocity equation, it is clear that the lower the porosity value, the higher the magnitude of the velocity estimate. Hence, lower porosity values will result in more conservative estimates of velocity, all other factors being equal. Given this consideration, the lowest porosity value, 0.43, was selected from Table E.4-2 and was used in all subsequent computations.

Hydraulic Gradient. The last factor in the Darcy velocity equation that must be obtained from field data is the hydraulic gradient. The gradient was determined from potentiometric contour maps, which were prepared from water-level data gathered throughout the study area. The preparation of the contour maps was discussed previously in this section, and the maps are provided as Figures E.4-8 through E.4-9. For the calculation of Darcy velocities, the contour maps prepared from the November and December 1985 water-level data were used.

Hydraulic gradients for each of the test wells were selected from the contour map. The values denote gradients ranging from 0.019 to 0.038 (foot per foot) across the study area for the lower aquifer. An average gradient of 0.028 can be calculated from this range. For the upper aquifer, the range was 0.010 to 0.023, for an average of 0.019.

Each of the individual gradients, however, was used in the calculation of the individual "point" velocities at each of the 13 successful test locations shown on Figure E.4-6.

Velocity Computation. Using the values presented above, individual velocities were computed for each of the 14 test well locations. These values are presented in Table E.4-4. The individual point values are also presented on Figure E.4-6.

The computed velocities for the lower aquifer ranged from a minimum of 2 feet per year at Well D-27 to a maximum of 13 feet per year computed at MW-5, with an arithmetic mean value of 7 feet per year. For the upper aquifer, the computed velocities ranged from 12 feet per year at MW-11 to 82 feet per year at MW-1, with an arithmetic mean value of 47 feet per year.

#### E.4.2.4.3 Groundwater Availability

Based on the results of the aquifer tests and the interpretation of site subsurface geologic conditions, some general statements regarding overall groundwater availability can be made. The current data base suggests that the water-bearing zones present at the ESII site are low in water yield and exhibit low transmissivities. These findings are generally consistent throughout the study area, with the exception of the northwest and northeast portions of the site, where somewhat higher transmissivity values are experienced. These higher transmissivity values, however, are still in the 10 to 100 ft<sup>2</sup>/day order of magnitude, which would rate the northwest and northeast portion of the site as having only a fair domestic well potential. The remaining segments of the site would, at best, qualify as having poor or infeasible domestic well potential. These concepts of well potential were discussed in Section E.4.2.3.3, where U.S. Bureau of Reclamation well potential criteria were compared with the measured site transmissivity data.

Given the dimensions of the ESII study area, an approximation of the overall daily flow of groundwater in the two aquifers

beneath the site can be made. This volumetric estimate is termed the average horizontal flux. The estimate is based on the average groundwater velocity computation and the average saturated thicknesses of the upper and lower aquifer zones. The computation for the upper aquifer is as follows:

$$\text{Average Flux (ft}^3/\text{day)} = VLbn$$

Where:

V = average groundwater velocity (ft/day)

L = average width of the site, perpendicular to flow direction (ft)

b = average saturated zone thickness (ft)

n = porosity

$$\begin{aligned} \text{Average Flux} &= (0.13)(1000)(5)(0.43) \\ &\approx 279 \text{ cubic feet per day} \end{aligned}$$

This calculation suggests that approximately 279 cubic feet (ft<sup>3</sup>) of groundwater flows beneath the site each day in the upper aquifer under steady-state conditions. This flux value is very small relative to values that may be seen in high-yielding aquifers, where flux values above one million ft<sup>3</sup>/day may be realized for sites having areal dimensions equivalent to ESII Site B.

Using the same approach for the lower aquifer indicates about 31 cubic feet groundwater per day are passing beneath the site.

#### E.4.2.4.4 Groundwater Recharge

Regional Recharge. Regional studies suggest several possible mechanisms for recharge to the shallow system saturated zones within the Glenns Ferry Formation. These mechanisms are:

1. Upward migration of deep artesian system groundwater along regional faults, with subsequent lateral migration into the Glenns Ferry Formation
2. Interconnection with saturated alluvium along principal surface water drainages in the region
3. Upward leakage from the deep artesian system through overlying confining layers

No definitive regional studies have been performed to examine in detail the quantitative role played by each of these postulated mechanisms. All, however, are regarded as likely.

The concept of captured recharge from surface water systems appears to be particularly applicable to the Site B setting. The site is located approximately one mile from Castle Creek, a principal regional tributary to the Snake River. Castle Creek is located on the upgradient side of Site B, based upon the eastward groundwater flow directions established for beneath the site. Castle Creek is perennial and has been shown in regional studies to have a zone of saturated alluvium in hydraulic connection with the stream channel.

Another possible source of recharge, principally to the upper aquifer zone, is local irrigation. About one-half mile northwest of the site, agricultural fields are irrigated with water obtained from the Snake River. Normal irrigation practices require excess application of water to leach the root zone. This water may then be available for groundwater recharge.

Although both aquifers flow eastward, the shape of the potentiometric surface for the upper aquifer differs from that of the lower aquifer, suggesting a component of inflow from the northwest. The change in shape may be the result

of the lateral inflow of irrigation-derived groundwater from the northwest, whereas the lower aquifer may be recharging from Castle Creek to the southwest.

*Recharge*

Onsite Recharge. Surface-derived recharge to the groundwater system at Site B is considered to be insignificant because of the semi-arid precipitation conditions (7 to 8 inches per year), the high evaporative rate (approximately 80 inches per year), the dense clay beds overlying the upper aquifer. Data presented in Table E.4-2 indicate low soil moisture levels in the upper 100 feet, further indicating surface recharge is not a significant mechanism recharging the upper aquifer at the site. On a regional scale, such processes may be important, especially in areas where topographic depressions can store local surface runoff. No regional quantitative water balance studies have been performed, however, to evaluate the natural infiltration component of the regional groundwater budget.

Although the onsite infiltration component is considered negligible or nonexistent as a source of groundwater recharge, a groundwater age study was performed to further examine the issue. The results of the study are presented below.

Groundwater Age Dating Analysis. To test the hypothesis that the recharge may be from a local source (in particular, precipitation infiltration at or near the site), a groundwater sample from Well MW-1 was collected and submitted for tritium analysis.

Tritium is a radioisotope of hydrogen with an atomic weight of three. It decays by pure beta emission with a half-life of 12.33 years. Tritium is formed in the upper atmosphere by cosmic-ray spallation and by the interaction of fast neutrons with hydrogen.

Tritium is also produced by aboveground nuclear weapons testing. The first tritium from this source was detected in 1952, and by 1954 the "nuclear tritium" was substantially greater than the background of 8 tritium units (TU), or 25.76 pci/L in equilibrated natural waters. The nuclear tritium reached a peak in 1963 when the concentration in the northern hemisphere exceeded background by approximately three orders of magnitude.

The use of tritium to age-date groundwater recharge (removed from contact with the atmosphere) before 1952 is based on radioactive decay of tritium and the background concentration of about 8 TU. Age-dating of groundwater recharged after 1954 is based on correlation of multiple tritium concentrations with known fallout peaks. To interpret the calculated age of a single sample based on decay, it is important to note that the actual age can never be younger than the calculated age, no matter when the recharge took place.

The analysis shows that the sample contained less than 2 pci/L tritium. Based on a half-life of 12.33 years and an assumed initial tritium concentration of 25.76 pci/L, the calculated age of the water is greater than 45 years. Since the age of the water is greater than 45 years, the water in the upper aquifer beneath the site is not due to infiltration of recent local precipitation.

### E.4.3 SITE HYDROCHEMISTRY

#### E.4.3.1 SITE HYDROCHEMICAL MODEL

Because of the observed spatial variability in the common-ion hydrochemical data obtained during the Site B characterization efforts, a conceptual hydrochemical model was developed for the site. The model (similar to models postulated to

explain uranium "roll front" deposits) was developed to help explain several hydrochemical patterns that have been observed in the present data base. In general, these patterns show an increase in the concentrations of upper aquifer sulfate, total dissolved solids, hardness values in a downgradient direction beneath the site, and a decrease in alkalinity. An observable contrast between the chemistry of the upper aquifer and the lower aquifer is also supported by the present hydrochemical data. The lower aquifer is a sodium-bicarbonate-type water, while the upper aquifer is a calcium-magnesium/bicarbonate-sulfate-type water. Chloride concentrations are generally higher in the lower aquifer than the upper aquifer. This finding is true throughout the entire area of study.

The objectives of the hydrochemical modeling efforts were twofold:

1. To examine whether natural phenomenon or waste management practices are responsible for the observed common-ion hydrochemical patterns
2. To examine whether the observed hydrochemistry is consistent with hydraulic and geologic interpretations of site conditions

In response to these objectives, the hydrochemical modeling efforts examined the following:

1. The distribution of sulfate, total dissolved solids, hardness, and alkalinity in the upper aquifer
2. The geochemical reactions that govern the natural chemical evolution of groundwater in both aquifers

3. The spatial variability in hydrochemical values that could be expected under natural conditions at or near Site B
4. The differences in chloride values observed between the upper and lower aquifers
5. The effect of the hypothetical mixing of waters from the upper and lower aquifers, in the event that hydrogeologic interpretations of the system are incorrect

To address the above concerns, a conceptual oxidation-reduction (redox) model was developed and tested. This model consists of the appropriate equilibrium geochemical reactions that might be expected to occur in various segments of the upper and lower aquifers. The segments investigated include the confined (artesian), the unconfined (water table), and the unsaturated zones of the upper aquifer, all of which occur beneath Site B, and the confined zone of the lower aquifer, which is the only zone in the lower aquifer occurring beneath Site B. Each of these zones is important in terms of its ability to allow oxygen (and other oxidizing agents) to come in contact with flowing groundwater. Such contact can induce a shift in the sequence of redox reactions that ultimately control the common-ion hydrochemical behavior of a natural groundwater system.

The steps that were executed in the effort were:

1. Development of the conceptual redox model and appropriate equations

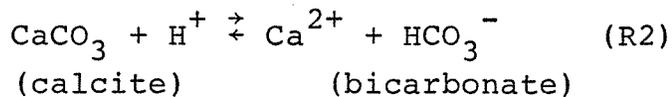
2. Determination of the quality or acceptability of all site hydrochemical data for subsequent inclusion in the model
3. Justification for deletion of unsuitable data (e.g., gross cation/anion imbalances)
4. Detailed examination of hydrochemical patterns observed in both aquifers across the site
5. Identification of probable geochemical reaction locations across the site (mapping of potential redox "cell" locations)
6. Laboratory identification of host minerals present in the subsurface to verify the conceptual geochemical and hydrochemical reactions postulated
7. Hypothesis testing of the upper aquifer using the USGS WATEQF equilibrium geochemistry model

It is emphasized that the objective of the conceptual hydrochemical modeling effort is to determine whether the variability in local scale common-ion concentrations that occur is a result of natural geochemical processes, rather than to predict the actual common-ion concentrations that have been observed in the monitoring area. Such predictions are beyond the scope of the effort because the actual distribution of host minerals and governing reaction sites is not known in sufficient detail. The effort's scope is to demonstrate the plausibility of natural variation as an explanation for the hydrochemical patterns observed in the present data base. The applicability and limitations of the conceptual model will be developed further in the following sections.



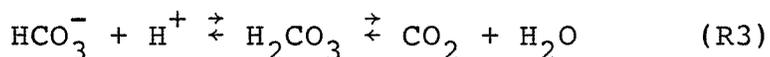
This reaction, which shows the oxidation of pyrite, consumes oxygen and produces sulfate and hydrogen ions. Both ions are free to move downgradient with the groundwater flow. However, the increase in hydrogen ions (acidity) results in another water/mineral interaction.

As shown below, calcite in an acid environment reacts to produce calcium ions and bicarbonate ions.



X-ray diffraction has indicated the presence of calcite in the aquifer. The increased acidity produced by the oxidation of pyrite forces the dissolution of calcite (and dolomite, if present). The dissolved calcium (to be referred to simply as calcium) that is released causes an increase in the hardness of the water. Such acid-neutralization reactions would be expected to occur in the immediate vicinity of the oxidizing pyrite. The calcium produced is then free to migrate with the flowing groundwater.

The increased bicarbonate resulting from calcite dissolution, along with the acidity of the first reaction, pushes the following reaction to the right.



The resulting carbon dioxide is then free to migrate upward. In this liquid environment, carbon dioxide (as a liberated gas) wants to move upward. This will cause an increase in the carbon dioxide concentration in the upper sections of the aquifer and drive Equations R3 and R2 to the left, causing calcite to precipitate. This also results in increased

acidity, which in the presence of clay is quickly exchanged for a sodium ion. The net effect is decreased carbon dioxide, decreased calcium, and increased sodium in the upper sections of the aquifer (i.e., updip).

Calcium moving with the groundwater will also produce geochemical changes down the hydraulic gradient. The increased calcium will cause Equation R2 to move to the left, resulting in calcite precipitation. Therefore, calcium and alkalinity (bicarbonate) are expected to decrease downgradient of the redox cell.

The redox cell is summarized on Figure E.4-10. As can be seen, the products that will be observed in the immediate vicinity of the redox cell are increased concentration of sulfate, hardness ( $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ), and carbon dioxide in the groundwater. Updip of the cell, limited carbon dioxide concentrations would cause decreases in calcium concentrations and increases in sodium concentrations. Away from the cell (downgradient), decreased concentrations of calcium and alkalinity are expected.

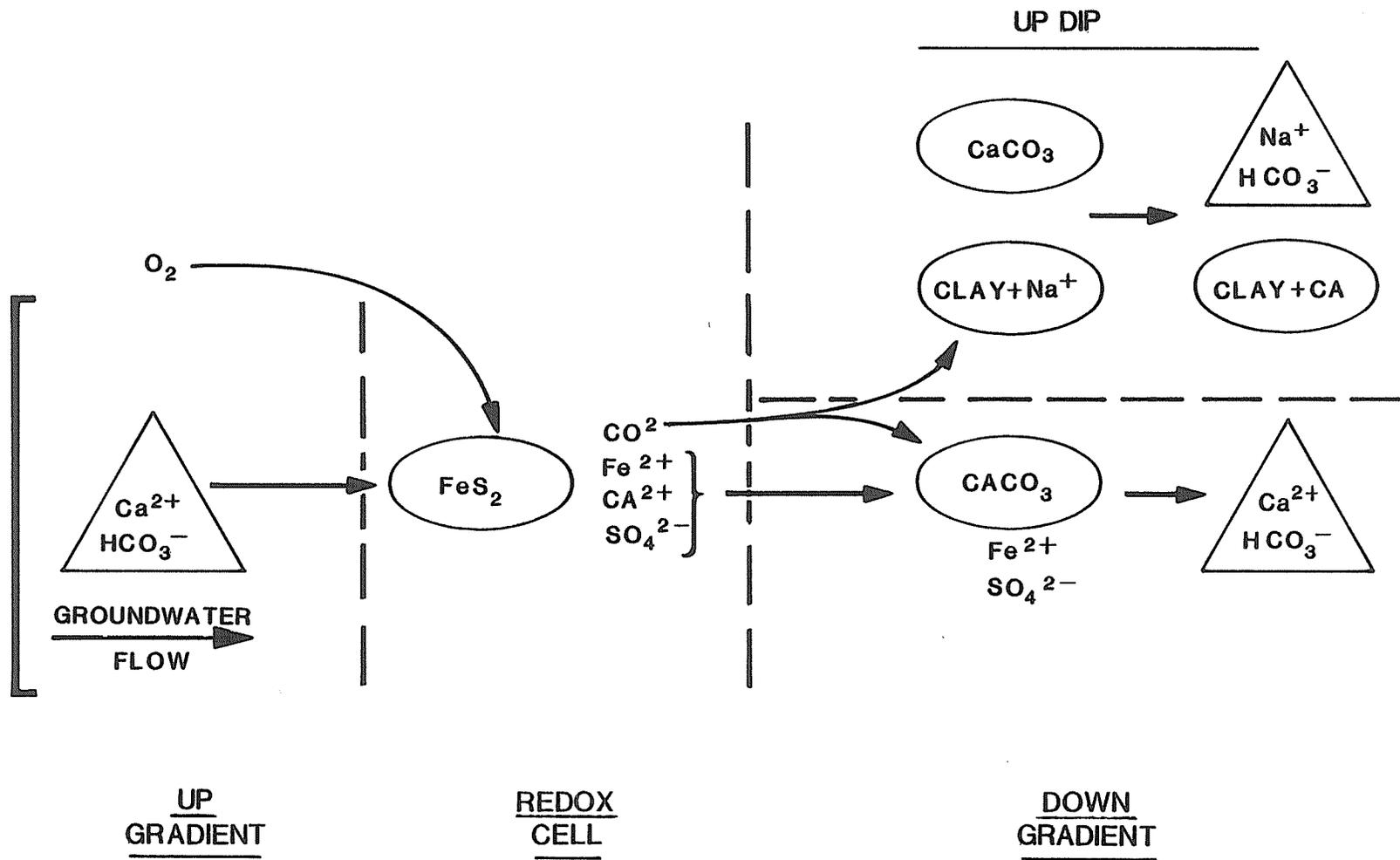
### E.4.3.3 METHODS

#### E.4.3.3.1 Data

Two different groundwater chemistry sampling programs have been conducted at the ESII site. These include a monthly RCRA Interim Status Detection Monitoring Program and a site characterization sampling program.

The monthly Detection Monitoring Program began in January 1984 with the sampling of MW-1 through MW-6. Currently, MW-1 through MW-6, MW-10 through MW-16, MW-21, MW-24, MW-25, the PCB wells, and the three SW (silo) wells are sampled.

UPPER  
AQUIFER



UP  
GRADIENT

REDOX  
CELL

DOWN  
GRADIENT

LEGEND

○ = CRYSTAL OR CLAY

△ = WATER TYPE

The primary purpose of the RCRA program is to satisfy regulatory requirements for the detection of potentially hazardous constituents in the groundwater at the point of compliance. Additionally, common-ion data have been generated by the program and analyzed to help clarify the hydrogeologic characteristics of the uppermost aquifers beneath the site. The data from this sampling program, and trend plots of various common ions for MW-1 through MW-6, and MW-15 are contained in Appendix F.

Supplementary to the RCRA Detection Monitoring Program, the site characterization sampling program was initiated to obtain a more thorough understanding of the site common-ion hydrochemistry. The results of this program are summarized in Table E.4-8. The data have been separated into upper and lower aquifer designations, based on zone of well completion. A summary of the data is shown in Table E.4-9. The summary includes both the range and the mean of the cations (positively charged ions), anions (negatively charged ions), field pH, temperature, and specific conductance.

Table E.4-8 contains chemistry data of water samples obtained from several small-diameter piezometers initially designed to measure area water levels. Although the piezometers were not designed for such purposes, samples were obtained from them in an attempt to provide a more complete data base. However, normal aquifer development and proper presampling purging could not be accomplished in the piezometers because of their depth and small diameter. For this reason, samples from the following stations are not considered representative of aquifer conditions and will not be used for interpretation: D-3s, D-3d, D-4s, D-4d, D-8s, D-8d, D-9s, D-9d, D-10s, D-10d, D-21s, D-23, and D-24s.

TABLE E.4-8

ESII - SITE B  
ANALYTICAL DATA

Page 1

## UPPER AQUIFER

CHEMICAL ANALYSIS	Date	Temp. (Deg. C)	SiO2	Ca	Mg	Na	K	Total Alkalinity	SO4	Cl	Ba	Fe	Mn	Specific Conductance (um/cm)	Total Dissolved Solids	pH Field /Lab (units)	F
SW-1*	6-85			104.0	63.9	182	42.0	680	180	60.0	0.20	10.00	0.42	1600		--/7.2	0.56
	9-85									43.3	<0.50	2.10	0.34			--/--	
SW-2	8-85	18.0	34	143.0	63.8	100	32.0	505	350	15.7	<0.50	6.60	0.57	1460	1060	6.9/7.3	0.80
SW-3	8-85	19.0	38	157.0	75.3	140	33.0	575	420	35.6	<0.50	15.00	0.61	1600	1250	7.1/7.3	0.86
	8-85	19.0	31	136.0	89.5	140	33.0	576	430	37.1	<0.50	15.00	0.61	1690	1260	7.1/7.2	0.88
PCB-1	8-85	19.0	37	54.0	49.8	230	27.0	626	87	61.5	<0.50	16.00	1.40	1430	912	6.7/7.7	0.64
	9-85									45.6	<0.50	0.14	0.41				
PCB-2	8-85	19.0	42	91.0	62.3	130	30.0	559	250	37.1	<0.50	6.10	1.10	1380	960	6.8/7.6	0.76
	9-85									36.6	<0.50	1.30	0.55				
PCB-3	8-85	19.5	46	130.0	53.2	120	29.0	384	430	15.3	<0.50	4.20	0.79	1400	1060	6.5/7.6	0.65
	9-85									13.7	<0.50	0.11	0.50				
MW-1	12-84			64.7	40.0	78	21.0	322	225	16.7	<0.10	2.90	0.11	920	646	--/7.5	0.83
	8-85	26.0	59	72.5	35.3	76	22.0	308	160	16.9	<0.50	0.19	0.04	963	654	7.2/7.5	0.79
	9-85									13.4	<0.50	0.42	0.03				
	9-85									13.3	<0.50	0.05	0.03				
MW-3	12-84			48.5	114.0	120	28.0	548	400	20.0	<0.10	4.30	0.33	1500	1080	--/7.3	0.81
	8-85	21.0	64	100.0	73.4	120	28.0	477	295	17.3	<0.50	0.34	0.33	1410	990	6.9/7.4	0.69
	9-85									17.7	<0.50	0.23	0.33				
MW-9	12-84			89.0	36.0	77	26.0	376	223	17.3	0.20	0.43	1.50	1010	724	--/7.5	0.81
	8-85	20.5	59	91.8	39.2	71	25.0	362	180	14.8	<0.50	9.50	0.45	1010	722	7.0/7.6	0.82
MW-10	12-84			178.0	<1.0	93	26.0	421	210	21.0	0.20	11.00	0.61	1110	802	--/7.5	0.82
	8-85	19.5	66	93.6	50.0	86	24.0	433	210	12.7	<0.50	0.14	0.19	1160	840	6.9/7.6	0.79
	9-85									12.8	<0.50	0.14	0.19				
MW-11	12-84			153.0	64.0	150	34.0	391	423	57.7	0.20	13.00	0.65	1710	1270	--/7.4	0.66
	8-85	20.0	62	159.0	77.5	150	30.0	594	390	48.0	<0.50	5.40	0.47	1780	1270	6.7/7.4	0.76
	9-85									39.4	<0.50	0.81	0.17				
MW-15	12-84			79.3	32.0	86	22.0	606	195	17.8	0.20	0.15	0.23	970	672	--/7.5	0.66
	8-85	15.0	60	79.1	36.4	77	24.0	365	138	11.6	<0.50	0.12	0.25	970	694	6.7/7.6	0.92
	9-85									25.3	0.50	0.35	0.09				
MW-16	8-85									52.7							
	9-85									51.3	<0.50	0.14	0.25				
	11-85			99.8	19.2	166	32.3	600	65	49.6	<0.10	1.03	0.24	1340	900	--/7.9	0.62
D-4s	12-84			63.1	15.0	82	21.0	577	155	35.1	0.50	12.00	1.10	820	550	--/8.5	1.50
D-8s	12-84			150.0	<1.0	70	15.0	285	220	118.0	0.30	1.30	0.03	1930	804	--/11.6	0.53
D-9s	11-84			67.2	11.0	77	15.0	218	124	172.0	1.50	30.00	2.10		600		0.70
	12-84			70.4	25.0	85	22.0	380	160	181.0	0.50	10.00	1.20	1040	612	--/8.5	1.35
D-10s	12-84			112.0	45.0	76	27.0	393	270	16.7	0.30	11.0	1.00	1120	796	--/8.3	0.90
D-18	12-84			56.6	29.0	78	19.0	553	160	14.6	<0.10	4.80	0.22	820	560	--/7.6	1.55
	8-85	18.0	55	68.7	27.9	75	20.0	302	140	13.2	<0.50	22.00	0.37	848	576	7.0/8.0	2.01
D-19	2-85			110.3	52.0	98	25.0	493	201	16.0	<0.50	4.10	0.24	1325	934	--/7.2	0.74
	8-85	20.0	63	124.0	73.0	91	28.0	484	360	15.3	<0.50	3.70	0.43	1420	1050	6.8/7.5	0.68

\* Results from ETC sampling. See Appendix F.

TABLE E.4-8

ESII - SITE B  
ANALYTICAL DATA

## LOWER AQUIFER

CHEMICAL ANALYSIS	Date	Temp. (Deg. C)	SiO <sub>2</sub>	Ca	Mg	Na	K	Total Alkalinity	SO <sub>4</sub>	Cl	Ba	Fe	Mn	Specific Conductance (um/cm)	Total Dissolved Solids	pH Field /Lab (units)	F
MW-5	12-84			64.7	42.0	180	20.0	613	4	58.3	0.80	0.97	0.90	1450	862	--/7.4	0.37
	8-85	19.4	47	67.5	45.4	180	20.0	615	7	99.1	0.90	0.40	0.10	1430	862	7.0/7.4	0.29
	9-85									88.2	0.80	0.35	0.11				
MW-6	12-84			52.6	34.0	210	18.0	718	12	38.8	0.70	0.62	0.82	1420	892	--/7.6	0.28
	8-85	25.0	45	50.0	36.6	220	18.0	715	8	35.3	0.70	1.10	0.08	1420	890	7.1/7.6	0.24
	9-85									27.1	0.60	0.40	0.07				
MW-12	12-84			64.7	32.0	170	21.0	492	75	111.0	0.40	5.10	0.40	1340	822	--/7.4	0.71
	8-85	22.5	42	67.7	41.4	190	21.0	611	17	114.0	0.80	1.70	0.22	1440	854	6.9/7.4	0.69
	9-85									116.0	0.90	0.54	0.14				
MW-13	12-84			52.6	19.0	160	18.0	522	110	34.5	0.70	13.00	1.10	1050	652	--/7.7	0.35
	8-85	23.0	31	51.0	27.9	190	16.0	566	68	39.0	<0.50	4.30	0.50	1220	744	6.9/7.7	0.40
	9-85									32.6	0.50	0.05	0.16				
MW-14	8-85	18.0	42	44.4	28.3	210	17.0	683	12	38.5	0.70	6.30	0.49	1280	812	6.95/7.9	0.22
MW-21	4-85			8.5	2.1	160	42.0	300	26	54.1	1.60	24.00	2.20	814	498	--/8.4	0.68
	8-85	15.5	46	20.7	17.9	150	22.0	410	22	46.4	<0.50	2.50	0.17	937	582	7.4/8.4	0.42
MW-24	4-85			61.7	27.0	135	21.0	487	10	78.0	0.80	2.90	0.21	1133	648	--/9.3	0.55
	8-85	21.0	41	51.5	30.8	160	22.0	535	18	66.4	0.80	2.80	0.28	1180	684	7.4/7.7	0.33
MW-25	9-85									25.3	0.50	0.35	0.09				
	11-85			49.1	7.0	171	25.5	536	16	24.8	<0.10	0.20	0.06	1100	715	--/7.9	0.78
D-10d	12-84				33.0	91	22.0	318	150	42.6	0.30	4.10	0.34	940	586	--/8.5	0.81
D-17	12-84			38.8	12.0	70	16.0	513	36	30.2	0.20	8.60	0.23	630	364	--/7.7	0.63
	8-85	18.0	26	55.0	37.5	110	20.0	503	22	73.8	0.60	9.40	0.97	1050	634	7.3/7.7	0.29
	8-85		27	59.5	45.9	110	19.0	560	25	74.9	1.00	22.00	1.70	1050	650	--/7.7	0.23
D-27	11-85			57.2	14.0	250	20.3	654	67	27.5	0.28	0.02	0.10	1400	1315	--/7.7	0.36
D-28	11-85			60.5	16.6	192	21.8	527	28	58.5	0.50	<0.01	0.14	1250	875	--/7.6	0.35
D-29	11-85			42.5	17.8	282	23.0	682	93	47.0	0.38	0.02	0.14	1490	910	--/7.8	0.38
D-30	11-85			57.2	0.1	280	19.0	686	117	29.2	0.36	<0.01	0.11	1510	1235	--/7.7	0.34
D-31	11-85			54.0	18.8	217	21.5	655	16	35.5	0.38	0.03	0.10	1300	810	--/7.7	0.33

TABLE E.4-8

ESII - SITE B  
ANALYTICAL DATA

Page 3

## SPAN UPPER AND LOWER AQUIFERS\*\*

CHEMICAL ANALYSIS	Date	Temp. Deg. C (Deg.C)	SiO2	Ca	Mg	Na	K	Total Alkalinity	SO4	Cl	Ba	Fe	Mn	Specific Conductance (um/cm)	Total Dissolved Solids	pH Field /Lab (units)	F
MW-2	8-85	24.0	59	152.0	65.6	83	31.0	450	360	17.9	<0.50	0.54	0.32	1430	1070	7.0/7.5	0.69
	9-85									12.4	<0.50	0.11	0.34				
MW-4	12-84			117.0	42.0	130	25.0	527	320	187.0	1.00	1.10	0.13	1560	962	--/7.6	0.55
	8-85	21.0	42	75.1	66.7	130	26.0	486	52	168.0	1.00	0.83	0.15	1510	894	7.0/7.5	0.48
	9-85									174.0	1.00	0.56	0.17				
MW-26	9-85									12.8	<0.50	<0.05	0.09				
	11-85			47.4	6.0	102	22.3	369	50	13.3	<0.10	0.02	0.07	890	580	--/7.9	0.92
D-3d	12-84			32.8	7.0	120	13.0	290	94	14.6	0.20	0.97	0.09	780	456	--/8.5	0.71
D-4d	12-84			59.0	<1.0	100	43.0	127	425	20.0	9.00	340.00	21.00	770	540	--/10.5	1.14
D-8d	12-84			72.8	<1.0	140	13.0	79	218	202.0	0.30	3.90	0.22	1100	656	--/9.8	0.72
	9-85		22	58.5	<1.0	200	16.0	328	65	135.0				1190	716	--/8.7	0.65
D-9d	11-84			224.0	<1.0	98	8.0	443	50	325.0	0.70	2.56	<0.05		1010		0.41
	12-84			111.0	<1.0	100	10.0	282	74	237.0	0.40	0.31	0.01	1770	802	--/11.4	0.55
D-20	2-85			53.5	30.0	227	21.0	728	11	26.8	0.60	8.10	0.24	1452	872	--/7.6	0.26
	8-85	22.5	39	49.8	37.9	230	25.0	901	7	35.3	1.70	21.00	1.40	1410	860	7.55/7.9	0.30

\*\* This grouping includes wells completed in sections other than the upper and lower aquifers.

TABLE E.4-9  
SUMMARY OF CHEMICAL ANALYSES

Compound	Upper Aquifer		Lower Aquifer	
	Range*	Mean*	Range*	Mean*
SiO <sub>2</sub>	31 - 66	51.1	26 - 47	38.6
Ca	48.5 - 178.0	101.6	8.5 - 6.7	51.4
Mg	<1.0 - 114.0	46.7	0.1 - 45.9	25.5
Na	71 - 230	107.7	70 - 282	177.7
K	15.0 - 42.0	26.2	16.0 - 42.0	21.1
Ba	<0.10 - 1.50	0.4	<0.10 - 1.60	0.6
Total Alkalinity	218 - 680	461.8	410 - 718	560.9
SO <sub>4</sub>	65 - 430	243.1	4 - 150	41.7
Cl	11.6 - 181.0	37.3	24.8 - 116.0	55.2
Field pH	6.5 - 11.6	7.3	6.9 - 9.3	7.5
Specific Conductance (umhos/cm)	820 - 1780	1219.1	630 - 1510	1210.2
Temperature (Degrees C)	15 - 26	19.5	15.5 - 25.0	20.3

\*Part per million (ppm)

#### E.4.3.3.2 Common-Ion Interpretation

Interpretation of the common-ion data began with data quality verification. Data were checked for anion/cation imbalances, and ion versus specific conductance cross plots were developed (see Appendix F). Ion imbalances greater than 10 percent were considered unacceptable. Six of the 14 samples of the December 1984 sampling had unacceptable ion balances. The August and November samplings had only two imbalances. These were D-18 and PCB-1, with imbalances of 11 and 13.5 percent, respectively. In addition, MW-5 was an outlier on the ion/specific conductance cross plots and is considered questionable.

Differences and similarities between water chemistry of samples from different aquifers are best shown graphically by a Piper diagram. The Piper diagram uses the percentage of the major cation and anion milliequivalents per liter on a trilinear diagram (Figures E.4-11 and E.4-12). The Piper diagram graphically shows the differences in water type.

The data plotted on Figures E.4-11 and E.4-12 are divided into two water types. The upper grouping contains most of the upper aquifer wells and indicates a calcium-magnesium-bicarbonate-type water for the upper aquifer. The lower group, which contains the lower aquifer wells, indicates a sodium-bicarbonate-type water for the lower aquifer.

As would be expected, all the samples (designated upper or lower based on screened interval) fell within the appropriate groups when plotted, except for PCB-1 and MW-16. The PCB-1 sample results are considered questionable because of an ion imbalance, as discussed above. The ion imbalance, which is normally due to laboratory error, is sufficient to cause PCB-1 to plot low.

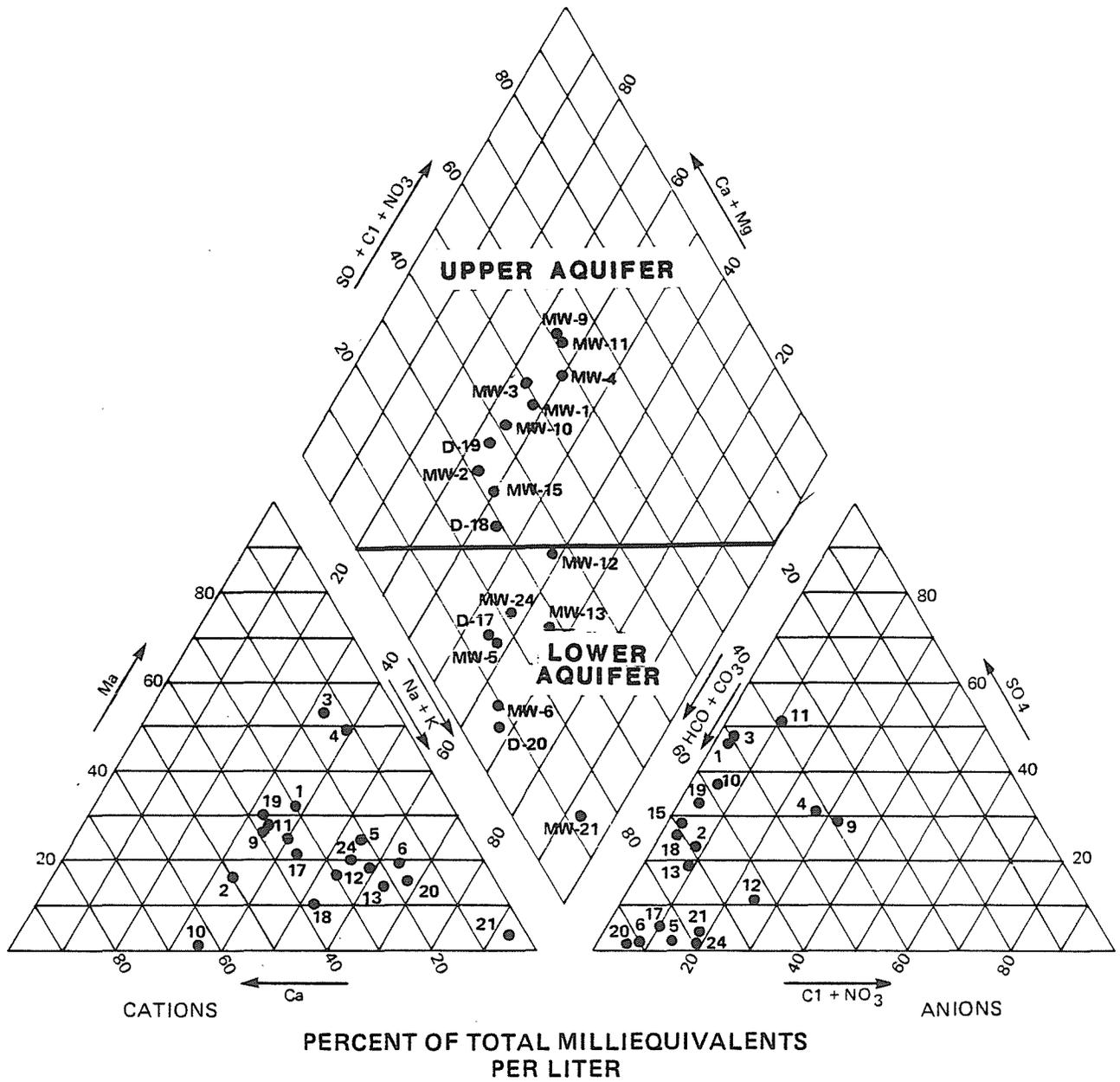
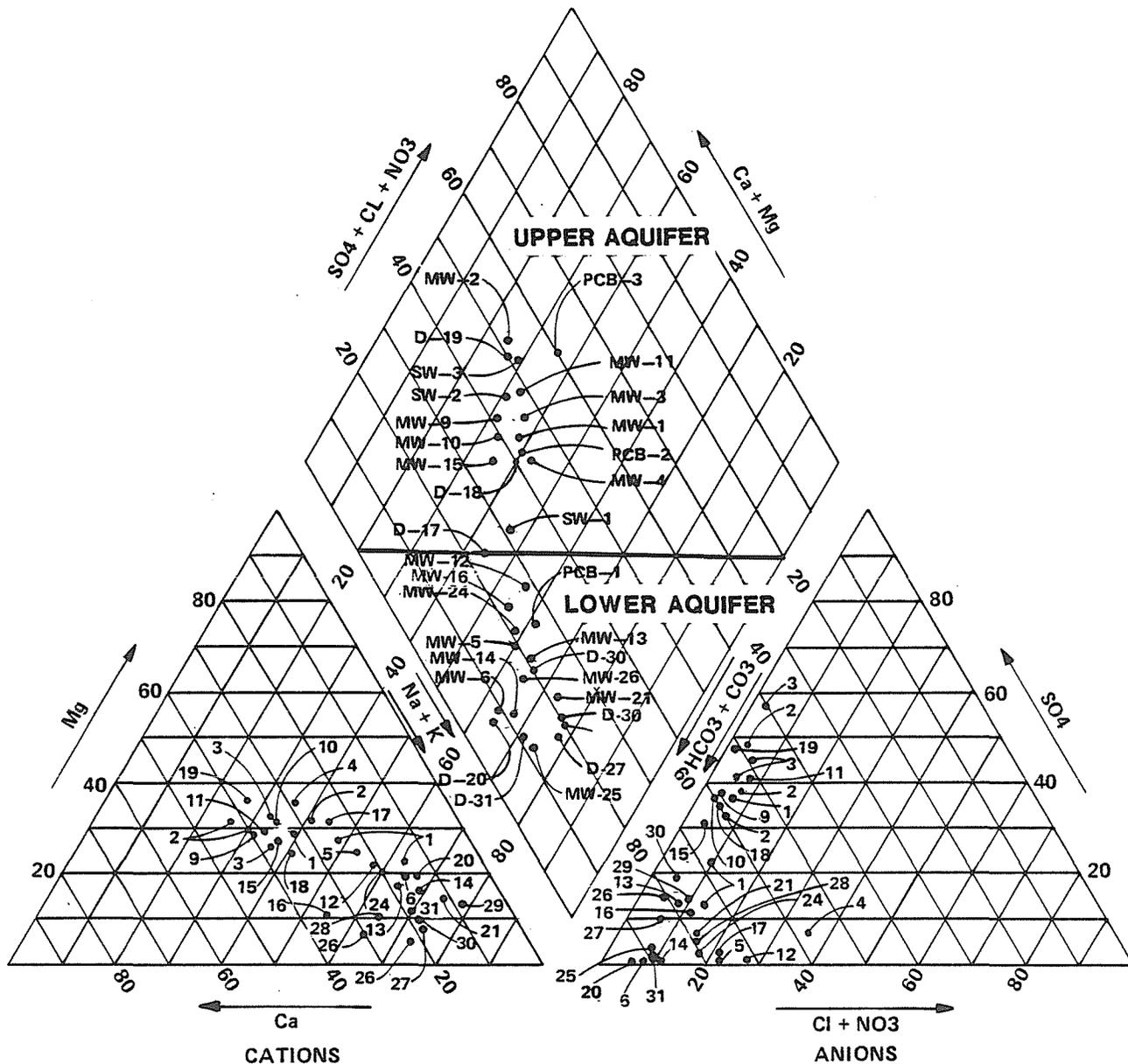


FIGURE E.4-11  
 PIPER DIAGRAM  
 (FOR SAMPLINGS  
 BEFORE JUNE 1, 1985)  
 ESII SITE B





PERCENT OF TOTAL MILLIEQUIVALENTS  
PER LITER

FIGURE E.4-12  
PIPER DIAGRAM  
(FOR SAMPLINGS  
AFTER JUNE 1, 1985)  
ESII SITE B



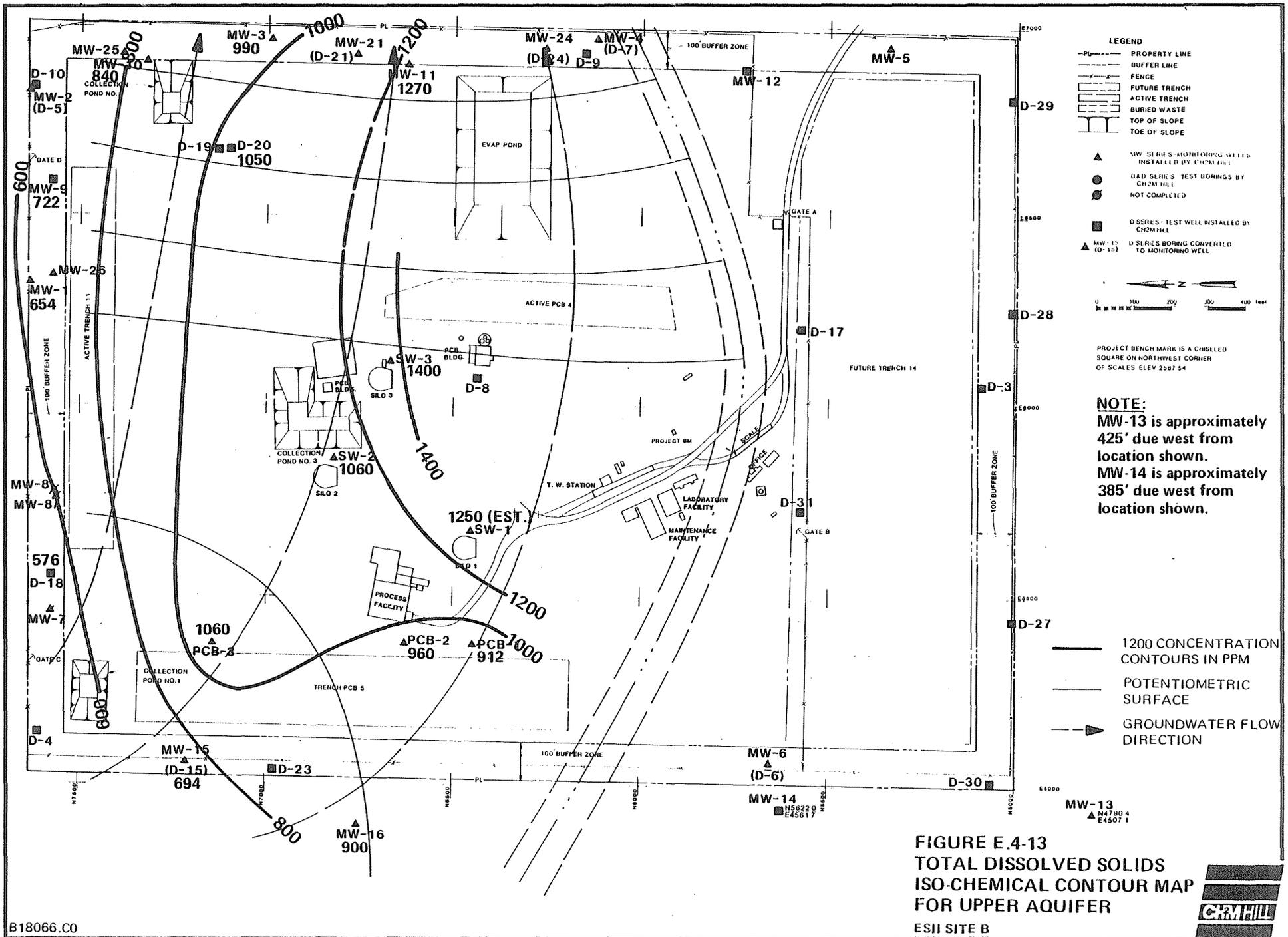
Well MW-16 also falls into the lower aquifer cluster on Figure E.4-12. Well MW-16 is screened strictly within the upper aquifer, and the laboratory analysis is within reasonable balance limits. The presence of lower aquifer-type water in the upper aquifer in this well is believed to be due to natural hydrochemical reactions occurring in the active oxidation-reduction cells present in the upper aquifer as described in detail in Section E.4.3.2.

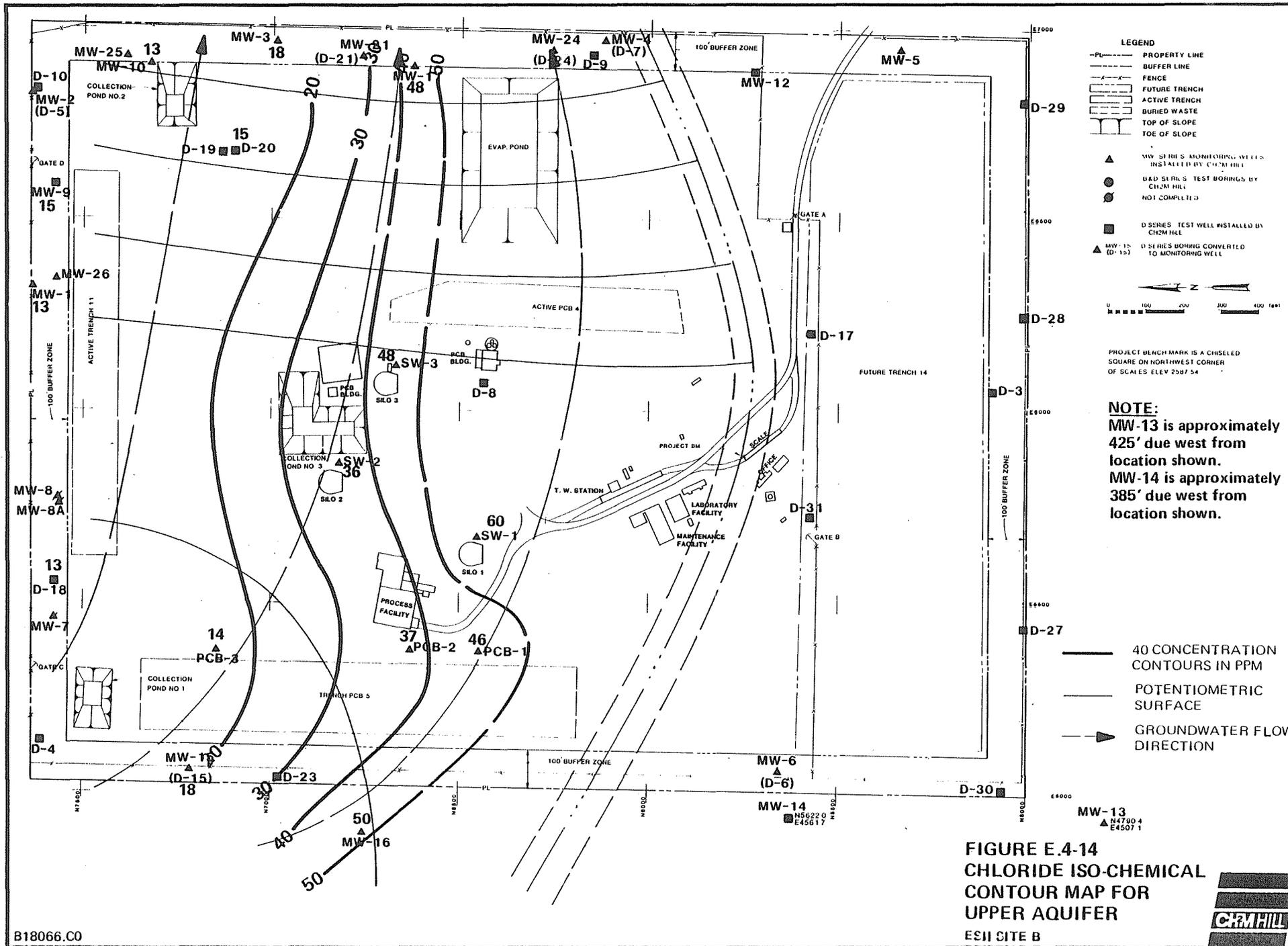
Wells that span both the upper and lower aquifers typically plotted in the upper aquifer group if the upper aquifer is saturated at that location. This suggests the upper aquifer is more permeable and thus contributes more water to the well than the lower aquifer.

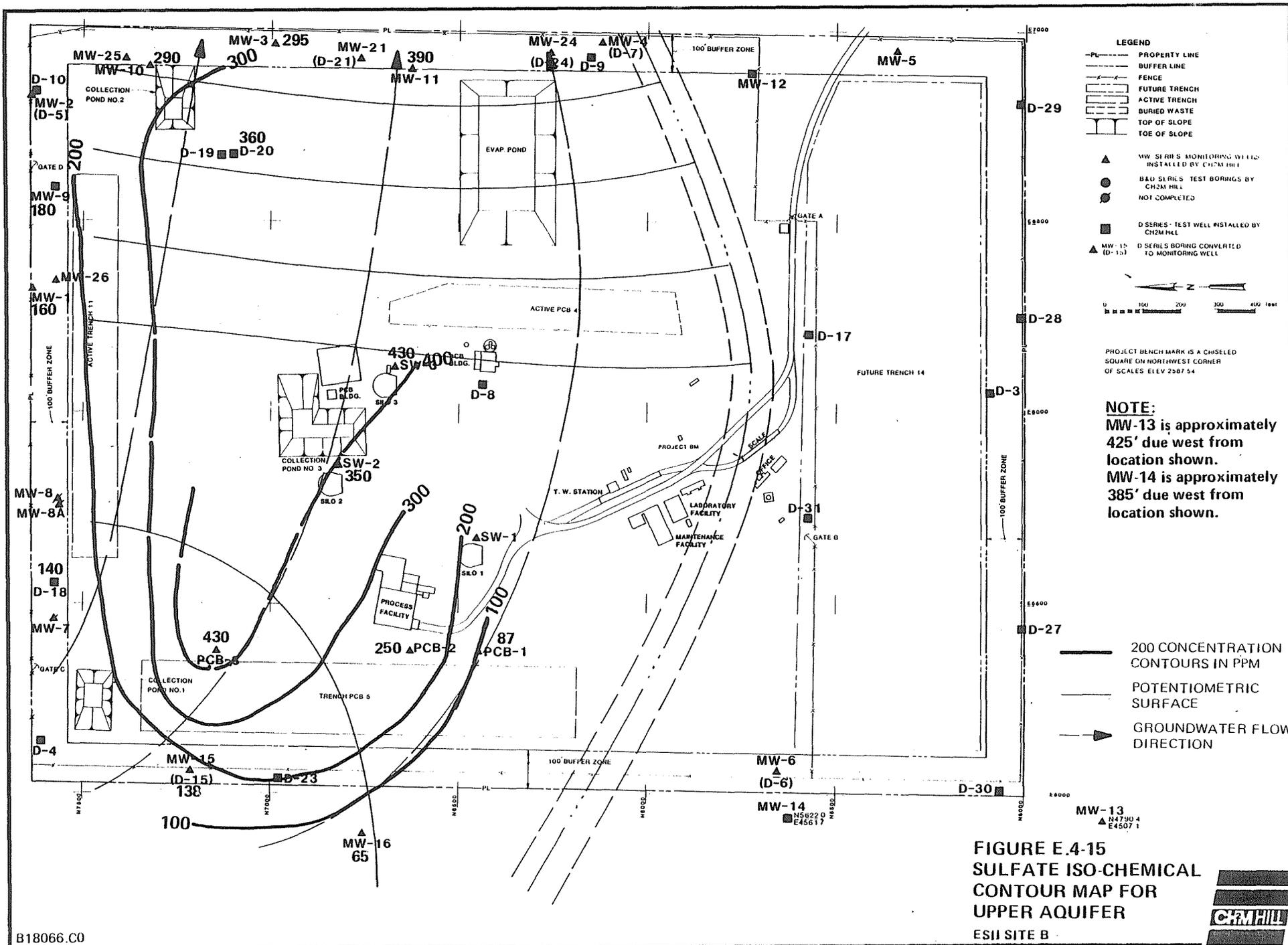
#### E.4.3.3.3 Iso-Chemical Contours

Maps showing isopleths, or iso-chemical contours, of various ions for upper and lower aquifers are presented on Figures E.4-13 through E.4-22. These figures have been prepared for TDS, chloride, sulfate, calcium, and magnesium. The maps show the ion concentration and the apparent change in concentrations across the site. The potentiometric surface is also shown for comparative purposes.

In the following discussion, the contour maps are presented for each aquifer, followed by comparisons between the aquifers. Chemical gradients are also compared (see Table E.4-10) and are defined as the change in concentration per foot (units of ppm/foot). The maps are based on the August 1985 sample results for all wells, except D-27 through D-31 which show November 1985 values and SW-1 for which June 1985 values are used.

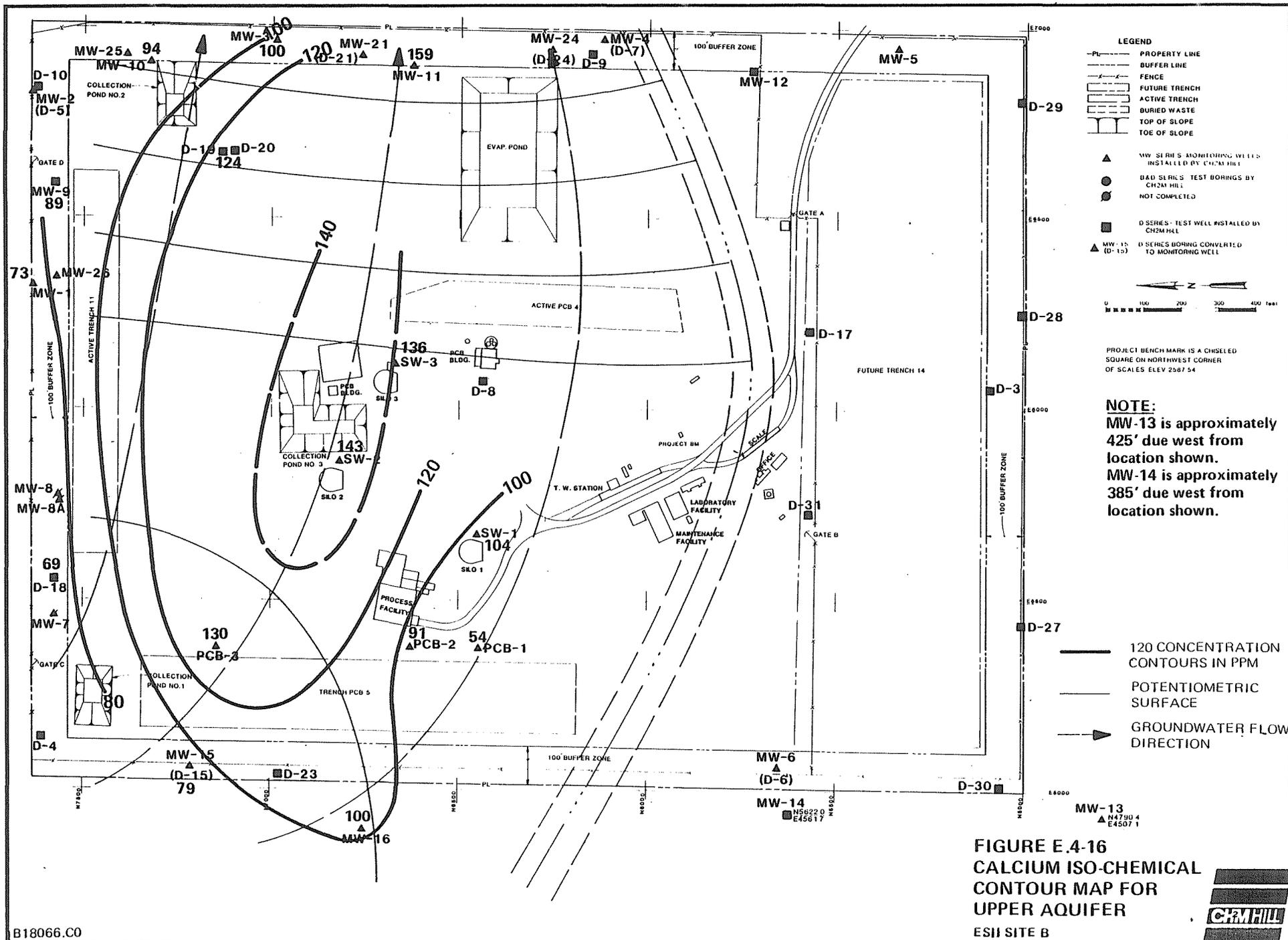






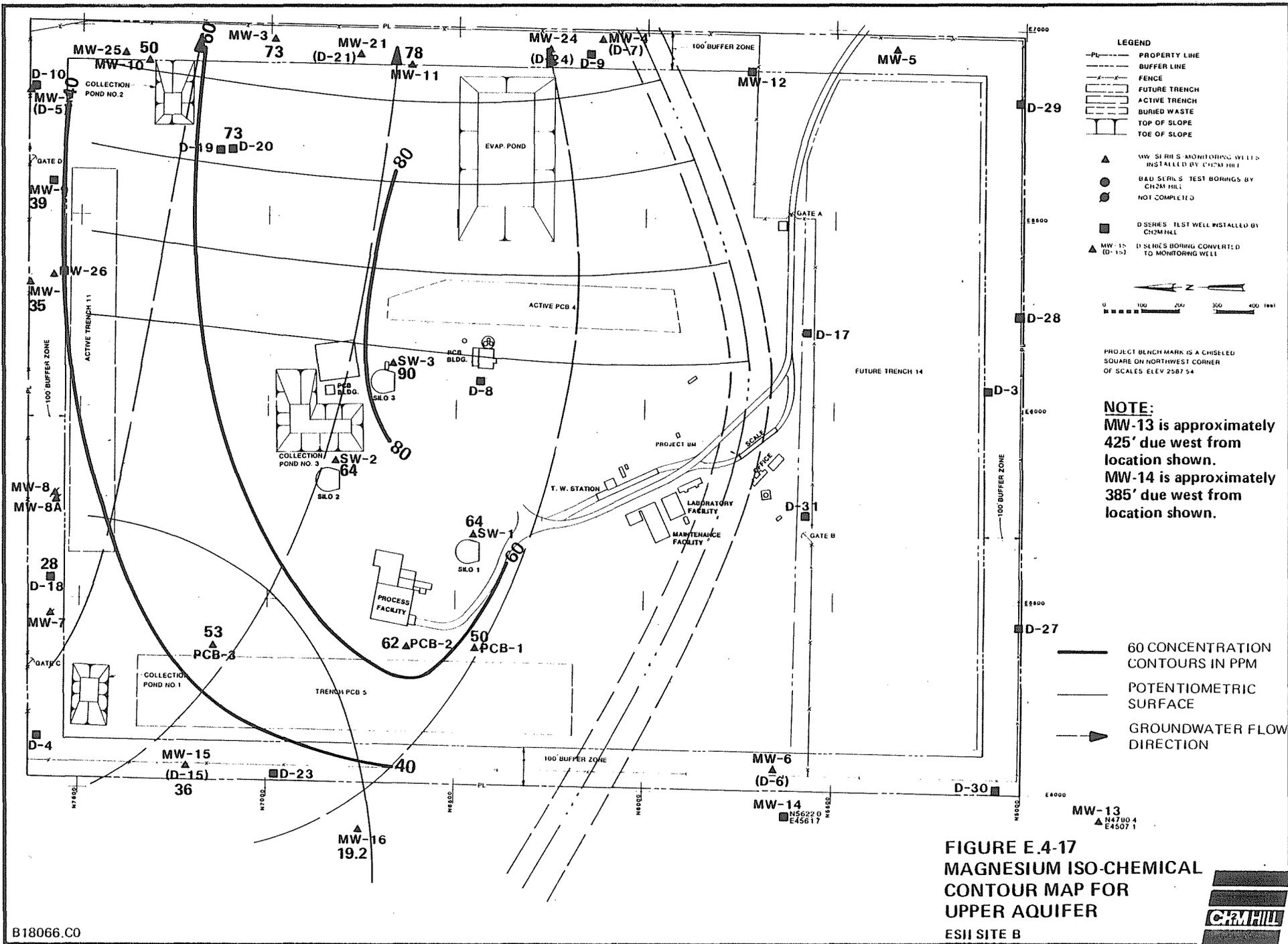
**FIGURE E.4-15**  
**SULFATE ISO-CHEMICAL**  
**CONTOUR MAP FOR**  
**UPPER AQUIFER**  
**ESII SITE B**

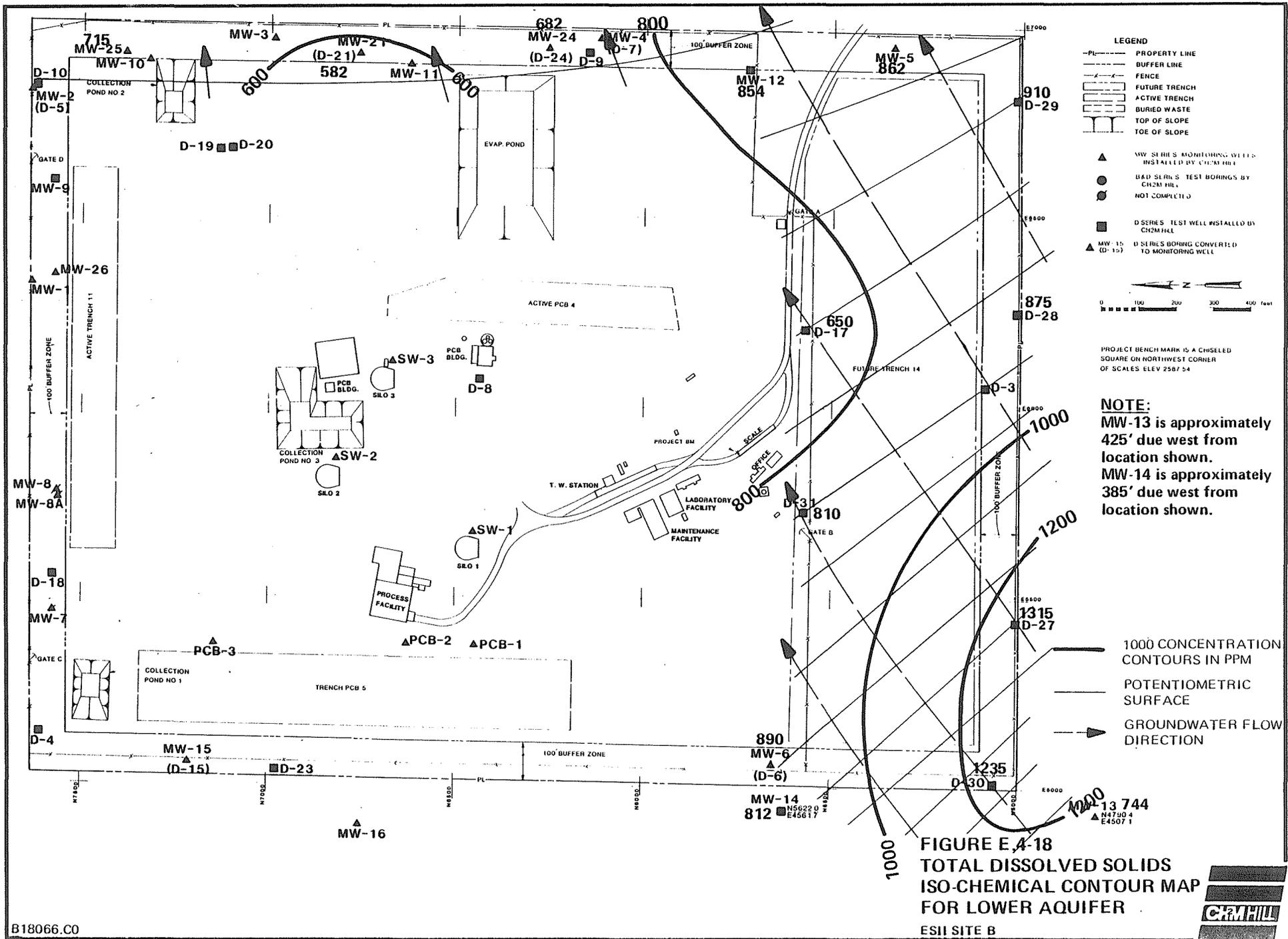


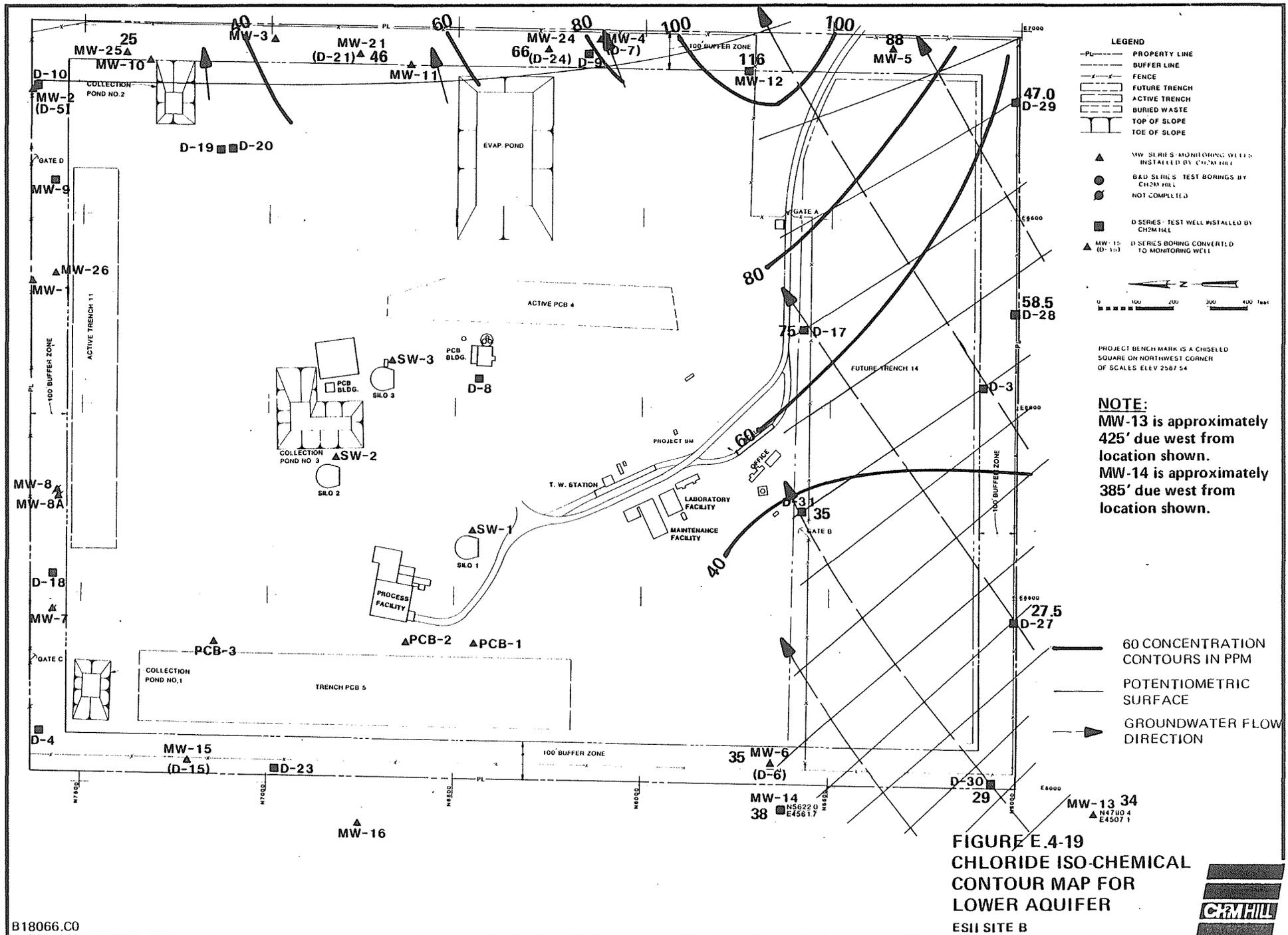


**FIGURE E.4-16**  
**CALCIUM ISO-CHEMICAL**  
**CONTOUR MAP FOR**  
**UPPER AQUIFER**  
 ESII SITE B



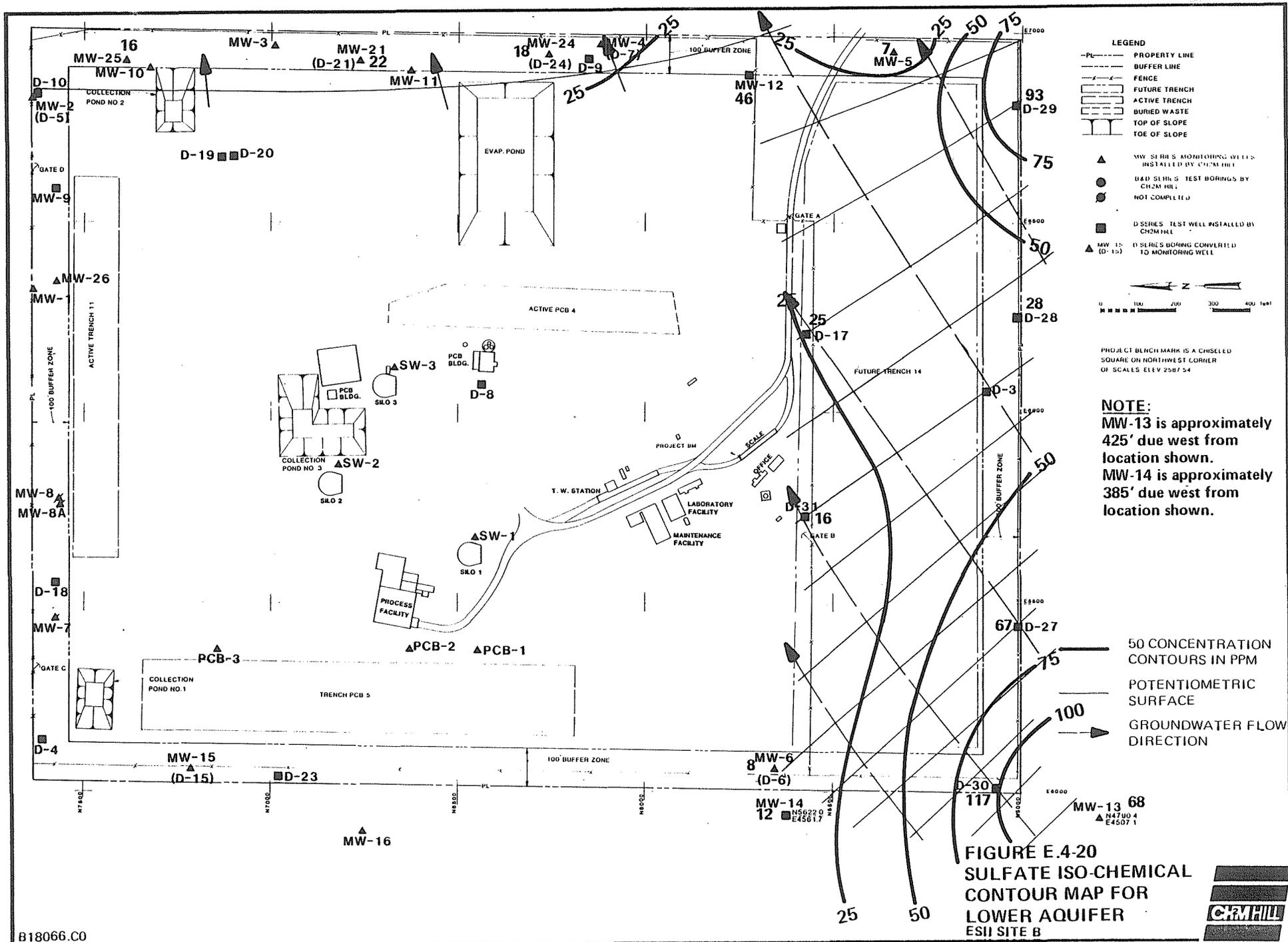






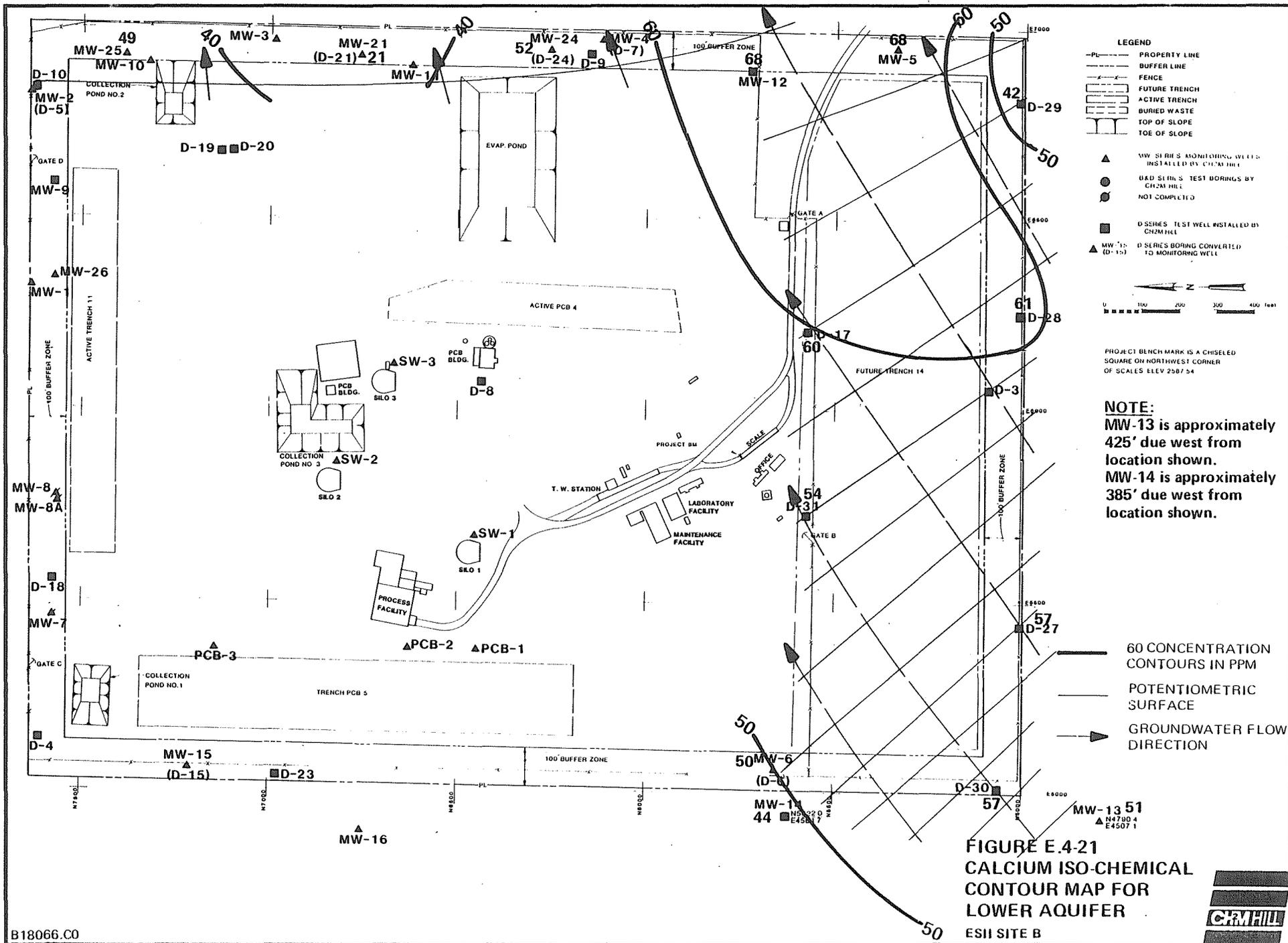
**FIGURE E.4-19**  
**CHLORIDE ISO-CHEMICAL**  
**CONTOUR MAP FOR**  
**LOWER AQUIFER**  
**ESII SITE B**

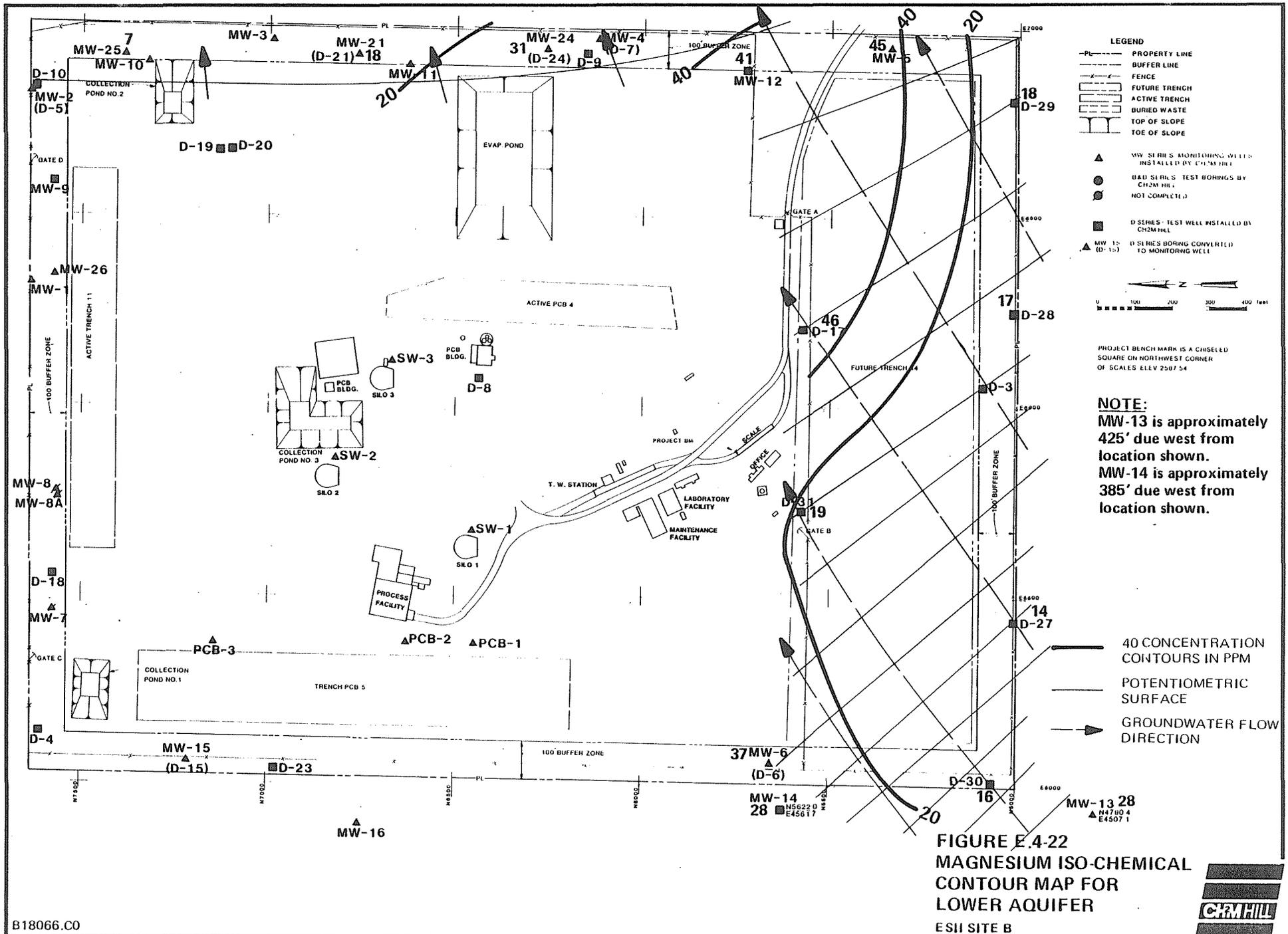




**FIGURE E.4-20**  
**SULFATE ISO-CHEMICAL**  
**CONTOUR MAP FOR**  
**LOWER AQUIFER**  
**ESII SITE B**







**FIGURE E.4-22**  
**MAGNESIUM ISO-CHEMICAL**  
**CONTOUR MAP FOR**  
**LOWER AQUIFER**  
**ESII SITE B**



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Table E.4-10  
MAXIMUM CHEMICAL GRADIENTS  
(ppm/ft)

	<u>Upper Aquifer</u>	<u>Lower Aquifer</u>
TDS	1.6	.67
Chloride	.05	.07
Sulfate	.80	.19
Calcium	.20	.05
Magnesium	.07	.10

---

Upper Aquifer Isopleth Maps. As can be seen on Figures E.4-13 and E.4-14, the TDS and chloride ion maps show decreasing concentration to the north. The chemical gradients are perpendicular to the groundwater flow path. The chloride contours extend offsite to the east and the west (both up- and downgradient).

Sulfate, calcium, and magnesium contours all have a similar character, with an apparent ridge of peak concentrations just north of midsite. The ridge appears to extend offsite to the east (down-hydraulic gradient). The sulfate gradient is the highest of all the individual species, as seen in Table E.4-10. The TDS gradient is higher than sulfate, but is a reflection of all chemical ions present.

Lower Aquifer Isopleth Maps. The common-ion data, and therefore the contours, for the lower aquifer are distributed along the eastern and southern portions of the site. Contour trends along the east side are variable and show no consistent pattern. TDS and sulfate contours (shown on Figures E.4-18 and E.4-20) at the southwest corner are similar and appear to reflect concentrations increasing uphydraulic gradient to the southwest.

Aquifer Comparisons. Based on comparisons along the north-east section of the site where maps overlap, there is little correlation between upper and lower aquifer chemical contours and ion concentrations. All ion concentrations, except chloride, are higher in the upper aquifer. Chloride and magnesium have similar chemical gradients in both the upper and lower aquifers. Sulfate and calcium gradients are higher in the upper aquifer.

Discussion. The chemical variations seen in the upper aquifer for TDS, sulfate, calcium, and magnesium suggest the presence of an active redox area. The above constituents all increase in the redox area and tend to decrease down-hydraulic gradient. In the lower aquifer, a similar redox area may exist off the southwest corner of the site.

As discussed above, there is little correlation between the chemical gradients or concentrations of any ions in the upper and lower aquifers. This indicates that there is no mixing of water between the aquifers. It is also apparent that the calcium and sulfate are spatially related in the upper aquifer, but unrelated in the lower aquifer.

#### E.4.3.3.4 X-Ray Diffraction Mineralogy

The geochemical relationships of the groundwater combine the geologic setting and geohydrology with the chemistry of the groundwater to arrive at an explanation for the aquifer chemistry that is consistent with all three elements. The general geologic setting has been defined in Section E.4.2. The specific geologic setting necessary for an understanding of the mineral-water chemical reactions includes the site-specific whole-rock mineralogy.

Core samples of the Glenns Ferry upper and lower aquifer sands and clays above and within the upper aquifer section

from various test holes were submitted for semiquantitative mineralogic determinations using whole-rock X-ray diffraction. A total of 50 samples from eight drill holes were analyzed to determine the whole-rock mineralogy of the site from the surface through the first water-bearing sand layer(s). Table E.4-11 is a list of the indicated minerals in each sample by peak height. Peak height in this table is in counts per second (cps) and is indicative of the relative abundance of the mineral in the total sample. The peak height underestimates the clay mineral abundance so that the clay minerals cannot be compared directly with other minerals in the sample but they can be compared with clay minerals in other samples.

Quartz is ubiquitous and clearly the most abundant mineral in every sample. It is more abundant in the upper part of the section than in the lower part. Samples that are designated sand, however, clearly have higher peak heights than silts and even more than clays. For example, sands always have a peak height of 1,000 and the best sands have a peak height greater than 2,000 cps. Clays, on the other hand, frequently have quartz peaks of less than 1,000 cps. Silts have a quartz peak intermediate between clay and sand.

Feldspars and carbonates are the second most abundant minerals making up the whole-rock mineralogy. The feldspars are generally dominated by plagioclase (sodium- and calcium-rich) but include potash (potassium-rich) feldspar as well. Clays and some silts are frequently low in feldspar with peak heights of less than 100 cps. The carbonates, calcite, and dolomite are present throughout the section, but calcite is typically more abundant in the upper part of the section. Both the feldspars and the carbonates are most abundant in the sands. This is anticipated for the feldspars but the carbonates' abundance in the sands indicates a possible secondary mobility and precipitation of carbonates in the pore space of the sands.

*This sample  
Vadose zone*

Table E.4-11  
X-RAY DIFFRACTION WHOLE ROCK MINERALOGY--ESII  
SITE B

Well	Description	Depth	Peak Height - (CPS)											
			Clay			Sand/Silt		Carbonates			Pyrite	Gypsum	Clino <sup>c</sup>	Chab <sup>d</sup>
			Mont.	Illite	Kaolinite	Quartz	Plagioclase (Feldspar)	Calcite	Dolomite					
D-10	Clayey Silt	215	15	44	8	1971	250	392	412	12				
	Clayey Silt	235	15	7	6	1362	83	156	123	58				
D-22	Sand	140.5 & 143.7 <sup>a</sup>	13	10	5	1600	98	108	100	13	9	1	13	
	Clay	144.6	17	11	12	1190	61	159	108	5	-	3	6	
	Clayey Silt	155	16	17	7	1282	52	149	100	5	6	-	4	
	Sandy Silt	160	20	12	5	1018	56	132	96	12	-	-	16	
	Gray Sand	161.2	10	28	14	1436	188	296	253	8	4	5	4	
	Gray Sand	164.2 & 165.7 <sup>a</sup>	22	22	16	1892	180	372	272	7	7	5	14	
	Gray Sand	168.5 & 169.6 <sup>a</sup>	11	30	17	1640	112	246	303	13	6	2	-	
	Clayey Silt	174	25	8	7	1183	53	164	104	7	-	-	8	
	Gray Sand	181.7 & 182.3 <sup>a</sup>	19	25	15	1584	156	313	231	9				
D-23	Silty Clay	50.8	16	18	5	1056	77	185	27	8	6	-	15	
	Tan Sand	147.4	17	15	6	1452	196	146	94	7	-	11	16	
	Clayey Silt	150.4	12	16	12	1129	48	225	96	8	-	-	5	
	Gray Sand	159.3 & 157.9 <sup>a</sup>	19	27	6	1980	81	237	166	5	-	5	19	
	Silty Gray Clay	164	17	24	6	999	86	177	137	5	-	4	12	
	Gray Sand	168.2	15	17	8	2218	139	193	306	6	-	6	-	
	Gray Sand	171.2	16	37	10	2294	303	262	404	5	3	15	17	
	Clayey Silt	176.6	13	26	14	992	49	310	199	5	-	-	7	
	Gray Sand	187.0	21	31	8	1731	202	185	250	6	-	2	10	
D-32	Sand	131.8 & 132.4 <sup>a</sup>	19	29	9	1505	114	250	213	9	6	-	13	
	Silty Clay	141.7	13	21	9	1076	26	240	121	7	-	-	-	
	Clayey Silt	146.6	18	14	8	1274	66	125	92	5	-	7	10	
	Tan Sand	147.2	19	13	6	1823	745	240	196	11	4	-	-	
	Tan Sand	152.0	19	36	14	2181	253	199	276	20	7	2	-	
	Gray Sand	156.5	13	28	7	1849	174	240	240	28	-	2	6	
MW-21 (D-21)	Silty Clay	44.7	25	40	14	1289	98	11	19	5	-	2	-	
	Sand	161.6 & 162.8 <sup>a</sup>	17	34	7	1399	188	253	292	5	5	26	8	
	Clayey Silt	182	21	13	10	1429	81	123	112	5	-	3	11	
	Sand	205.5	11	34	12	1840	146	169	135	32	-	-	-	
	Sand	208.7	12	14	5	2873	254	228	188	12	1	-	15	
	Sand	217.5	15	35	10	1459	92	237	250	10	-	-	11	
PCB-1	Silt	165	21	22	5	986	132	262	137	29	18	1	-	
	Silt	181.1	21	28	10	1347	74	400	216	8	1	-	-	
	Sand	185	35	24	10	2421	228	253	231	12	-	-	22	
PCB-2	Clayey Silt	170	17	25	15	1163	441	292	234	10	-	-	-	
	Clayey Silt	180	14	18	11	1452	310	365	313	5	-	-	2	
	Sand	188	14	25	10	2725	317	207	169	12	-	15	10	
SW-1	Silt Clay	162	15	16	12	1482	130	256	216	12	3	-	-	
	Tan Sand	166	13	18	8	1980	320	202	210	6	17	3	7	
	Gray Clayey Silt	180	16	26	12	1109	79	266	159	10	-	6	20	
	Gray Sand	190	18	18	11	2134	376	237	159	10	-	11	2	
SW-2	Sand	165	18	27	9	2025	234	237	339	5	5	-	4	
	Tan Clayey Silt	167	18	19	5	1600	110	234	225	8	-	3	2	
	Gray Clayey Silt	178.5	16	5	18	18	1584	66	159	108	-	-	-	
	Gray Sand	185	27	20	18	2061	151	190	234	14	-	7	22	
	Gray Silt	191	22	27	11	1310	128	353	286	7	6	-	-	

<sup>a</sup>Composite sample

<sup>b</sup>Montmorillonite

<sup>c</sup>Clinoptilolite CaAl<sub>2</sub>Si<sub>7</sub>O<sub>8</sub>·6H<sub>2</sub>O (also K)

<sup>d</sup>Chabazite Ca<sub>2</sub>Al<sub>4</sub>Si<sub>5</sub>O<sub>24</sub>·12H<sub>2</sub>O (also Na)

The mixed-layer clay is made up in varying proportions of montmorillonite (calcium and sodium), illite, and kaolinite. A significant amount of montmorillonite was detected in all samples. One of the primary roles of the clay minerals in the aquifer is the exchange of sodium and calcium. It is common for these lacustrine clays to exchange calcium in the recharge water for sodium held by the clay.

Pyrite is also present in each sample. The quantity of pyrite varies throughout the sections, with a greater abundance indicated in the sandier samples.

The presence of pyrite suggests a neutral-to-alkaline, reducing, slightly saline-to-saline, lacustrine environment typical of most western Tertiary-Age volcanic tuffs. The tuffs were deposited in ephemeral lakes in an arid-to-semiarid environment. This suggests that there has been little freshwater moving through this section since deposition and subsequent diagenesis.

It can be concluded that the Glens Ferry Formation at the site is representative of a brackish to slightly saline, low-energy lacustrine depositional environment. In addition, the site-specific geologic setting determined from the mineralogy is consistent with the geohydrologic setting described in this report.

A comparison of calcite peak heights for comparable samples from sands in SW-2 with SW-1, PCB-2 with PCB-1, and D-21 with D-22 clearly indicate that calcite abundance increases updip to the south (190 versus 237, 365 versus 400, and 169 versus 372, respectively). A comparable case for an east-west increase or decrease parallel to flow lines cannot be demonstrated. This strongly supports the hypothesis of carbon dioxide migrating updip leading to precipitation of

calcite in the pore space and reducing the permeability of the sands in a southerly direction.

Of particular interest are the relative amounts of pyrite and kaolinite occurring in the samples. Oxidation-reduction is indicated when the peak height of kaolinite is relatively high and the peak height of pyrite is relatively low (compared to other values in the same section). This is seen when kaolinite and pyrite values are compared (Table E.4-11). The mechanisms responsible are the oxidation of pyrite and the subsequent weathering of plagioclase minerals to kaolinite, which occur in the slightly acidic environment resulting from the redox cell.

Confirmation of the pyrite oxidation process is also documented by the pyrite and gypsum distribution. The two highest peak heights for gypsum and therefore the two samples with the highest amount of gypsum are in the upper samples from PCB-1 and SW-1. Gypsum is an obvious and usual alteration product produced by the oxidation of pyrite in a carbonate host rock. A comparison of PCB-1 with PCB-2 and SW-2 with SW-1 clearly indicates that gypsum is much higher in the updip southern drill holes PCB-1 and SW-1. This indicates that the oxidation process is progressing from the south to the north based on water chemistry, as indicated previously.

Mineralogy data, particularly at SW-1, indicate that gypsum is deposited in a lateral rather than vertical sense. There is no indication of fluids moving from the surface down into the uppermost water-bearing layers. Notice that the pyrite in the sample at 162 feet is higher and the gypsum lower than those in the sample at 166 feet. Water moving from the surface downward would have the opposite effect oxidizing the uppermost sample more than the lower sample.

The zeolite mineral chabazite identified in earlier interim submittals is confirmed by these data as being widespread in the sands and is joined by a second common zeolite, clinoptilolite. It appears that chabazite is the more abundant of the two zeolites. Both zeolites were found at all locations tested. (Refer to Table E.4-11 and Figure E.3-1 for depths and locations.) From these data it can also be seen that zeolites are present in the clays above the upper aquifer. This is a very positive finding as both zeolites selectively sorb and/or form barriers to selected organics if they are present in water (aquifer or vertical recharge).

#### E.4.3.3.5 Other Geochemical Analyses

Total Organic Carbon (TOC). The total organic carbon of a selected group of samples from drill holes is presented in Table E.4-12. The first two samples were selected because they are rich in "carbonaceous trash" (leaf fragments, twigs, etc.) that have been carbonized. The total organic carbon is very low, indicating that the organic matter has been strongly oxidized.

Samples from Drill Holes D-23 and D-32 were selected to give an indication of the vertical profile for total organic content. The general pattern indicated by these samples is an increase of total organic content with depth. The upper sand (147.4 feet) for Drill Hole D-23 is particularly low in total organic content (0.05 percent).

The data show a normal oxidation of organic material at and near the surface and a general increase of organic content with depth. The total organic content of these samples is low for lacustrine-series rock. Most lacustrine rocks contain at least one percent total organic content, particularly

Table E.4-12  
TOTAL ORGANIC CONTENT

<u>Well</u>	<u>Depth (feet)</u>	<u>TOC (wt%)</u>	<u>Lithology</u>
D-21	44.7	0.07	Silty clay carbonaceous
D-23	50.8	0.12	Silty clay carbonaceous
D-23	147.4	0.05	Sand
D-23	164.0	0.30	Silty clay
D-23	176.6	0.27	Clayey silt
MW-25	205.0	0.21	Sand
D-32	156.5	0.16	Sand
D-32	189.0	0.22	Sand

ROCK EVALUATION ANALYSIS

<u>Well</u>	<u>Depth (feet)</u>	<u>S1 (mg/g)</u>	<u>S2 (mg/g)</u>	<u>S3 (mg/g)</u>	<u>Hydrogen Index</u>	<u>Oxygen Index</u>
D-21	44.7	0.07	0.03	0.20	42	285
D-23	50.8	0.19	0.08	0.33	66	275
D-23	147.4	0.05	0.00	0.29	0	580
D-23	164.0	0.13	0.10	1.07	33	356
D-23	176.6	0.04	0.08	0.56	29	207
MW-25	205.0	0.00	0.03	0.39	14	185
D-32	156.5	0.03	0.05	0.35	31	218
D-32	189.0	0.11	0.07	0.68	30	295

S1 - Free hydrocarbons milligrams of hydrocarbons per gram of rock

S2 - Residual hydrocarbon potential

S3 - Carbon dioxide produced from kerogen (natural hydrocarbon)

Pyrolysis - (milligrams CO<sub>2</sub>/gram of rock) 250°C-400°C

Hydrogen Index - milligrams of hydrocarbon per gram of organic carbon

Oxygen Index - milligrams of carbon dioxide per gram of organic carbon

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in "carbonaceous trash" type samples. Oxidation of pyrite may be responsible for the overall low total organic carbon.

Rock Evaluation Analysis. Rock evaluation analysis is a pyrolysis technique used by organic geochemists to provide information on the quantity, type, and thermal maturity of organic matter. Samples are heated in the absence of oxygen to distill off the free organic compounds and crack pyrolytic products from kerogen (in soluble organic matter). The first peak to pyrolyze off (S1) represents milligrams of "hydrocarbons" that can be thermally distilled from one gram of rock. The second peak (S2) is the "hydrocarbon" generated by pyrolytic degradation of the kerogen. The third peak (S3) is the carbon dioxide produced from kerogen pyrolysis in the temperature range from 250°C to 400°C.

These peaks are compared with the total organic carbon to give the hydrogen and oxygen indices of thermal maturity. The hydrogen index is calculated by dividing the S2 peak by the TOC, the oxygen index by dividing the S3 peak by the TOC. For comparison purposes, coal and kerogen from other areas have a hydrogen index that ranges from 80 to 480 and an oxygen index that ranges from 50 to 80 (Claypool and Reed, 1976, and Verheyen et al., 1984).

The rock evaluation analysis for the samples indicate a very highly oxidized kerogen in a very poorly permeable rock matrix. The high degree of oxidation is indicated by the very high oxygen index relative to a very low hydrogen index. The poor permeability is indicated by the higher, more volatile S1-type organic matter over S2-type organic matter. The clayey nature of the sands is clearly discernable in these results.

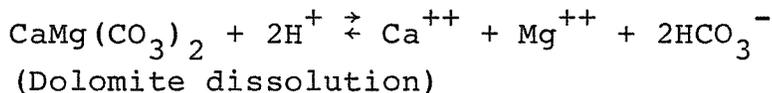
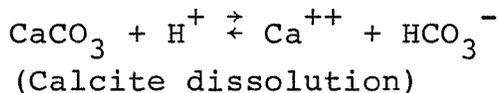
The results of the TOC and rock evaluation analysis are summarized as follows:

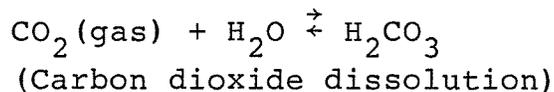
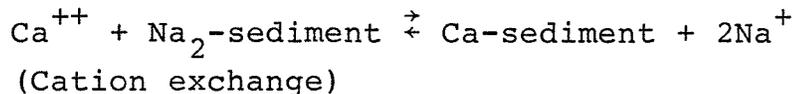
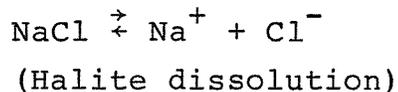
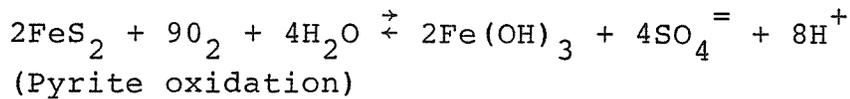
1. The TOC data indicate highly oxidizing conditions are present and this oxidation is less predominant with depth. TOC increases with depth.
2. The hydrocarbons present in the samples are highly oxidized and are very mature. By this evaluation technique, organic solvents and fossil fuels are very immature. If the source of hydrocarbon was from the surface, immature reduced hydrocarbons would be expected. Mature, oxidized compounds are present.

These two analytical techniques support the geochemical model of the site and provide additional data indicating surface recharge or site leakage has not occurred.

#### E.4.3.3.6 WATEQF Models

Chemical mass balance of well pairs along a groundwater flow path provides calculated solutions to chemical changes of the water by mineral-water interactions. Using the USGS equilibrium geochemistry computer program WATEQF, mass balance models were tested to determine reasonable mineral-water reactions based on directions of flow. Chemical reactions and equilibrium are calculated by the WATEQF program. Based on chemical and mineralogical evidence, the following reactions are proposed to occur for the upper aquifer:





The most suitable mass balance model for the approximate flow path MW-1 to MW-3 in the upper aquifer is:

Dissolution of

- 0.433 mmols/kg of  $\text{CaCO}_3$
- 1.152 mmols/kg of  $\text{CaMg}(\text{CO}_3)_2$
- 0.122 mmols/kg of  $\text{NaCl}$
- 0.702 mmols/kg of Pyrite [ $\text{FeS}_2$ ]
- 0.900 mmols/kg of Cation Exchange

Precipitation of

- 0.698 mmols/kg of  $\text{Fe}(\text{OH})_3$
- 0.087 mmols/kg of  $\text{CO}_2$  [evolves by gaseous diffusion across water table]

The most suitable mass balance model for the approximate flow path MW-15 to SW-2 in the upper aquifer is:

Dissolution of

- 0.911 mmols/kg of  $\text{CaCO}_3$
- 1.127 mmols/kg of  $\text{CaMg}(\text{CO}_3)_2$

0.116 mmols/kg of NaCl  
1.103 mmols/kg of FeS<sub>2</sub>  
0.444 mmols/kg of Cation Exchange

Precipitation of

1.099 mmols/kg of Fe(OH)<sub>3</sub>  
0.349 mmols/kg of CO<sub>2</sub> [evolves as gas]

Equilibrium calculations using WATEQF assess the degree of individual mineral saturation based on the water chemistry. Water samples from both aquifers are saturated (in equilibrium) to supersaturated with respect to calcite (CaCO<sub>3</sub>), dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>), and quartz (SiO<sub>2</sub>). This is not unusual for groundwater, as it ordinarily requires a certain amount of supersaturation (activation energy) to precipitate the mineral. Changes in total dissolved solids (ionic strength), temperature, or pressure, will also initiate precipitation of a mineral supersaturated in the groundwater. It is likely that calcite (and perhaps dolomite and quartz) is being precipitated from supersaturated groundwater.

The water in both aquifers is undersaturated with gypsum (CaSO<sub>4</sub>-2H<sub>2</sub>O), halite (NaCl), and sylvite (KCl). The equilibrium state of pyrite was indirectly assessed by the pH and the sulfate content in the groundwater, as well as the X-ray diffraction. Clay minerals were also approximated by the X-ray diffraction data. One of the primary roles of clay minerals in aquifers is sodium and calcium exchange.

E.4.3.3.7 Continuous Specific Conductivity

Continuous specific conductivity and temperature measurement have been taken from two wells for extended periods of time since January 1985. Conductivity and temperature data were

obtained with a Yellow Springs Instrument Model 3311 conductivity probe and a Campbell Scientific Model 101B thermistor. The probes were suspended in the wells and a Campbell Scientific data logger, Model CR-21, was programmed to collect a conductivity and temperature measurement every half hour. The probes were set at a depth of 200 feet in Well MW-10 from January 8, 1985, to February 1, 1985. On February 1, 1985, the probes were raised to 180 feet (3 feet below the water table). On March 11, 1985, the probes were moved to Well MW-12 (Figure E.3-2), and data were collected up through April 24, 1985.

Plots of the conductivity and temperature data recorded in these wells and the data tables are included in Appendix F. Water in both wells has a conductivity of about 1,070  $\mu\text{mhos/cm}$  and a temperature of 18°C.

It can be concluded from these data and from the ion trend plots in Appendix F that the aquifers at this site have very constant water quality over the period of record. There are no significantly different water chemistries moving through the wells over time, which would be indicative of pulses of recharge reaching the aquifers. There are insufficient data to determine the cause for the observed minor conductivity changes indicated in Appendix F.

#### E.4.3.4 DISCUSSION AND CONCLUSIONS

The redox cell concept was initially presented as a single cell to make it easier to understand. The redox zone is presented now as a more accurate representation of a complex, dynamic system, encompassing both aquifers on and adjacent to the site.

#### E.4.3.4.1 The Redox Zone

As discussed in the section on mineralogy, pyrite crystals are present in varying quantities throughout the sections sampled. This leads to the conclusion that the pyrite is disseminated throughout the geologic unit. When oxygen comes in contact with the disseminated pyrite, a redox cell will form. The redox zone can then be thought of as many small redox cells occurring wherever oxygen is present.

The oxygen is thought to enter the zone where the upper aquifer becomes unconfined. However, the aquifer is composed of many sand seams that become unconfined at the same general elevation (which may be termed a water table). Along this water table, there are many places where oxygen can enter the aquifer and produce redox cells. The redox zone, therefore, is the result of disseminated pyrite and many sand seams. However, it must be realized that oxygen can migrate down under osmotic pressure from the unconfined areas into the confined zone. A depth dimension is now added to the redox zone.

Finally, the hydraulic properties of the aquifer must be considered. Flow velocities in the upper aquifer range from 12 to 82 feet per year. These low velocities, when considered in a geologic time frame, are adequate to spread the redox products in the direction of groundwater flow. Also, vertical fluctuation in the potentiometric surface causes horizontal shifts in the redox zone. With the sand seams dipping at about 2 degrees, a water-level fluctuation of one foot would cause about 30 feet of lateral movement in the redox zone.

The existence and location of the redox zone is the result of all of these factors; therefore, the redox zone cannot be

concisely defined or precisely located. The redox products are, however, broadly present within the general area of the active redox zone.

#### E.4.3.4.2 Conclusion

Geochemical Variations. The redox zone has been presented as a mechanism capable of producing the hydrochemical variation observed in the upper aquifer. The Piper diagram indicates a calcium-magnesium-bicarbonate-type water with increased sulfate, as expected. The X-ray mineralogy results show the presence of disseminated pyrite, with an appropriate proportion of kaolinite. The WATEQF model verifies the plausibility of the water-aquifer interactions presented in the redox model. The hydrogeology presented in Section 4.2 shows that the upper aquifer is partially unconfined beneath the site, which provides a plausible source of oxygen for geochemical reaction. And finally, the iso-chemical contour maps for the lower aquifer suggest the presence of a second redox cell southwest of the site where, by projecting structural dip, the lower aquifer is expected to become unconfined. As there have been no waste disposal activities in that area, this suggests that the hydrochemical variation beneath the site is natural and not the result of past waste disposal activities.

The geochemistry lends further support to the separation of the two aquifers and is consistent with site hydraulic and geologic interpretations. The Piper diagrams show two different water types for the upper and lower aquifers, and the iso-chemical contour maps show no correlation between the upper and lower aquifers.

Chloride Data. The redox model does not address the minor variations seen in the chloride data. These variations

are believed to be due to natural geochemical variability. Comparison of the chloride values in the two aquifers beneath the site support a separation of the aquifers.

In the upper aquifer, the highest chloride gradients extend offsite (both east and west) and show no indication of a point-source leakage or a plume-shaped distribution. The chloride concentrations are higher in the lower aquifer than those in the upper aquifer, indicating that downward leakage is not responsible for the presence of variability of chloride values. This is further supported by soil chemistry data that show chloride concentrations in the sands and clays of the upper and lower aquifers increase with depth upgradient and downgradient of the site. Soil chloride data are provided in Appendix G.

A "ridge" of higher chloride concentrations exists beneath the eastcentral portion of the site (see Figure E.4-14). However, this ridge extends beyond the active area of the site and does not appear to reflect site activities. Finally, when the upper and lower variations are compared, no spatial correlation is observable. This is further verification of upper and lower aquifer separation.

BOT513/001

## E.5 WATER QUALITY

*Use New Data 7/8*

In addition to the common-ion data described in Section E.4.3, ESII has been collecting groundwater samples under 40 CFR 265 Subpart F [40 CFR 265.92(d)(2)] from six onsite RCRA monitoring wells on a monthly basis since January 1984. In 1985 ESII added a total of nine new monitoring wells into their RCRA Interim Status groundwater monitoring network. Currently 11 "downgradient" and four "upgradient" wells, 15 total, are being monitored on a monthly basis.

Sampling and analysis procedures have followed EPA regulations and guidelines to ensure that representative data are available. This section outlines the scope and methods used for collecting and analyzing the groundwater monitoring samples, a summary of the data collected, and the results and conclusions that can be drawn from that analysis.

### E.5.1 DESCRIPTION OF SAMPLING AND ANALYSIS PROCEDURES

*Procedure Manual*

The sampling and analysis procedures established by ESII follow Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, (EPA document SW-846 [10/4/83]), or the RCRA Permit Writer's Manual, Groundwater Protection 40 CFR Part 264 Subpart F (10/4/83), where possible. Any variations in sampling or analysis from these documents are equal to or exceed the regulatory requirements.

#### E.5.1.1 SAMPLING PROCEDURES

Pursuant to 40 CFR 265.92, ESII has developed Interim Status sampling procedures designed to collect the most representative sample possible from the groundwater aquifer under the site. The sampling procedure includes the following elements:

- o Sample collection
- o Sample preservation and handling
- o Chain-of-custody control
- o Analytical procedures
- o Field and laboratory quality assurance/quality control

#### E.5.1.1.1 Sample Collection

##### E.5.1.1.1.1 Measurement of Static Water Level Elevation.

Prior to purging or sampling each well, the elevation of the groundwater is determined, as required by 40 CFR 265.92(e). The well identification is welded onto the well cap. The well cap is unlocked and removed; on the bailed wells, the inner well casing cover is removed and the bailer is removed.

*Teflon probe  
black pump*

An electric tape water-level measuring device is used to determine the depth to groundwater. Prior to lowering the probe down the well, the end of the probe that will contact the water is rinsed with distilled water to remove any potential contamination. For the bailed wells, the probe is simply lowered down the inner casing. For the pumped wells, an access port is provided on top of the casing cap. The probe is lowered through this access port and down a 3/4-inch PVC pipe that extends down to groundwater. This pipe is designed to prevent the probe from becoming tangled in the pump piping and electrical wire in these wells. Once the depth to groundwater is determined, the probe is removed from the well and the end of the probe is again rinsed with distilled water to remove any potential contamination. Groundwater elevations are measured to the nearest one-half inch. Depth to the

bottom of the well is not measured except during well maintenance activities since it is available in site documents (see Table E.3-2 and Appendix B).

The well elevation relative to mean sea level has been surveyed by a registered surveyor. It has been related to a fixed reference point on the well casing. Pursuant to 40 CFR 265.92(e), the measured water levels are converted to elevations based on the surveyed datum and used in this determination.

E.5.1.1.1.2 Well Evacuation. Once the groundwater elevation has been determined, the wells are purged prior to sampling. These wells are used for monitoring only and are typically not pumped between sampling events.

While water within the screened portions of a nonpumping well may experience a continued exchange with formation water due to natural flow within an aquifer, limited vertical mixing of water occurs in the casing above the screens. Thus, water standing within a nonpumping well will tend to stratify and stagnate with time. Stagnant water in a monitoring well can develop substantially different chemical characteristics than groundwater in the formation surrounding the well.

Changes in the concentration of dissolved gases in the water within the well can occur. This is caused by exchange of gases across the interface between water and the atmosphere within the well. The result can be change in redox conditions and pH in the well. This change can be accompanied by changes in the chemical species present, precipitation or dissolution of metals, and the removal or addition of constituents due to subsequent sorption reactions.

The chemical quality of water standing in contact with well materials, such as the casing, screen, or grouting, for long periods of time may also be altered by leaching or adsorption of constituents from those materials. Biological activity within the well may affect certain chemical parameters as well. A common example would be sulfate reducing or iron bacteria that can be responsible for the formation of iron sulfide and iron hydroxide in the well. These compounds may then adsorb selected constituents. Biological activity may also be responsible for the degradation of certain biological constituents.

Because of the changes that could potentially occur as described above, all wells being sampled will first be purged. The RCRA Permit Writer's Manual for 40 CFR 264 Subpart F (10/4/83) recommends evacuating monitoring wells to dryness if possible. Therefore, the bailed wells are bailed dry and allowed to recover before sampling. The bailing cable is vinyl-coated and is cleaned between use in each well. The lower-yielding pumped wells are pumped dry and allowed to recover before sampling. The number of bails required to bail the well dry and the time required to pump the low-yielding wells dry is also recorded. Each bailed well has a dedicated bailer and each pumped well has a dedicated pump. Therefore, cross contamination that could result from using the same equipment in the purging operation is avoided. The bottom-valve bailers are 20 feet long and 2 inches in diameter and are constructed of PVC. The pumps installed in the pumped wells are Grundfos all-stainless-steel submersible pumps, Type SP1, Model SP1-16, 1/2 horsepower. The location of the pumps in each of the wells is shown in Appendix B.

Water evacuated from the wells is allowed to discharge onto the site. The topography does not allow the water to run

off the site. Those wells that can be evacuated to dryness are purged only one time. Therefore, parameters such as pH or specific conductivity are not monitored to establish well stabilization. This purging procedure has been maintained throughout the sampling program.

For those pumped wells that cannot be evacuated to dryness, three well volumes are evacuated to purge the well. The amount of time necessary to purge three well volumes is based on the maximum well volume and the sustainable yield for each well. Field data, including temperature, pH, and specific conductivity, are collected from the well discharge.

E.5.1.1.1.3 Sample Collection. Pursuant to 40 CFR 265.92(a)(1), sample collection procedures are described below. After the low-yielding wells have been purged and allowed to recover (typically one to 2 hours), they are sampled. For wells that cannot be pumped dry, samples are collected immediately after three well volumes have been removed. Samples are collected by the same techniques that are used to purge the wells. That is, the bailers are used to collect the samples from the bailed wells, and the pumps are used to pump water into the sample containers in pumped wells. Since each well has either a dedicated pump or bailer, cross contamination is avoided. Therefore, the only foreign material that the well water comes in contact with other than the sample containers is the PVC piping associated with the pumps, the bailers, and the vinyl-coated bailer wire. Sampling is conducted by a qualified third party.

When collecting samples, the sample containers used for volatile constituents are filled first. These samples are collected to minimize agitation or aeration to prevent loss of the constituent during the sample collection process.

Bailers are lowered carefully into the water to prevent degassing of the water upon impact, and the pumping rate for the pumped wells is throttled back so a slow, steady, non-aerated stream of water is available for filling sample containers.

E.5.1.1.1.4 Field Measurements. For the 1984 data base presented in this submittal, only temperature was measured in the field. This parameter was measured as soon as the sample was taken.

The pH of the 1984 samples was measured in the site laboratory. Normal laboratory procedures were followed in measuring these parameters. Specific conductivity was measured at the contract laboratory. Currently, three parameters--temperature, pH, and specific conductivity--are measured in the field.

Water for these determinations is collected in pre-rinsed one-gallon bottles. An aliquot of this water is used for each determination. This aliquot is then disposed of onsite.

Normal laboratory procedures are followed in measuring these parameters; that is, all meters will be allowed to warm up before being used. The pH meter is standardized with pH 7 and 10 buffers. The meter is also corrected for temperature before the pH is read. The pH standardization is determined repeatedly until the reading agrees within 0.1 pH unit.

The conductivity meter is calibrated within 0.01 N KCl before use. The temperature of the sample is measured as soon as it is collected.

E.5.1.1.2 Sample Preservation and Handling

A contract laboratory provides the sample containers and preservatives required for the sampling event. All sample

bottle preconditioning, such as baking or acid washing, is done by the contract laboratory. Appendix H shows the type of sample containers and preservation techniques that are used. This table was taken directly from EPA's RCRA Groundwater QA/QC Compliance Checklist (Appendix A), Revision 04-10-84, and is consistent with SW-846, Section 1.4.6.2.3. The volumes shown in the table are minimum volumes. Larger sample containers may be used.

All samples are preserved in the field except those that must be filtered first. Metal samples must be filtered before preservation and shipment. For these samples, water is collected in one-gallon bottles. The water is filtered on-site using 0.45-micron filters, preserved with nitric acid, and placed into the shipping shuttles. Prior to October 1985, samples were filtered in ESII's onsite laboratory. Since August 1985, the samples are filtered and preserved at the well site using portable 0.45-micron filters. The other sampling procedures described above have been consistent throughout the sampling program. In addition to the well samples, the sampling also includes the use of field blanks and trip blanks. These are discussed in the QA/QC section.

#### E.5.1.1.3 Chain-of-Custody Control

As required by 40 CFR 265.92(a)(4), the Interim Status Groundwater Monitoring Program in place for this facility includes chain-of-custody control to ensure against contamination of samples. ESII uses existing chain-of-custody record forms that are equivalent to the EPA Office of Enforcement chain-of-custody forms and the chain-of-custody form found in SW-846.

The sequence of events for controlling chain of custody is as follows: When the sample bottles are delivered from the

laboratory, the sender and receiver both sign and date the chain-of-custody form and specify on the form what has changed hands. From that point on, every time the sample bottles, whether empty or full, change hands, both parties sign and date the transfer. When sample bottles are delivered to the laboratory, a copy of the chain-of-custody form is retained for ESII files. A sample chain-of-custody form is included in Appendix H.

As seen on the chain-of-custody sample form, the following information is included:

- o Sample number
- o Signature of sampler
- o Date of collection (time logged in field log book)
- o Place and address of collection
- o Type of sample
- o Number and type of container
- o Inclusive dates of possession
- o Signature of receiver

In addition to the chain-of-custody form, other components of chain of custody have included sample labels, sample seals, field log book, sample analysis request sheet, and the laboratory log book.

1. Sample Label. A sample label is affixed to each sample bottle to provide the sample number.
2. Sample Seals. A seal is affixed to each sample shipping container (not each bottle). This seal has a serial number that corresponds to the number on the chain-of-custody form for that container. The seal is secured to the locking mechanism of the shipping container immediately after sampling

and is broken at the laboratory under chain-of-custody procedures.

3. Field Log Book. A bound field log book is kept for each sampling event. A copy of the field log book is kept at the facility and is available for inspection. The format for the field log book includes:
- o Facility name and address
  - o Name and signature of sample collector
  - o Purpose of sample and type (for example, required analyses for initial background data, routine detection monitoring, and resampling)
  - o Locations(s) or source of sampling (such as the monitoring well number)
  - o Time and date of sampling
  - o Pertinent well data (such as depth, water surface elevation, pumping schedule, and method)
  - o Sampling method (for example, bailer, suction-lift)
  - o Log number of each sample
  - o Appearance of each sample (such as color, turbidity, sediment, and oil on surface)
  - o Field observations/sampling conditions (such as weather)

- o Sample temperature upon sampling
  - o Analyses performed in the field
    - pH
    - Specific conductance
    - Others
  - o Sample storage (such as where and how; conditions such as heat and light; and number of sample seals)
  - o Name and location of laboratory performing analyses
4. Sample Analysis Request Sheet. Analysis request sheets are provided to the laboratory, with a copy kept with the field log book.
5. Laboratory Log Book. Laboratory control records are attached to the chain-of-custody form and a copy is kept at the facility.

E.5.1.1.3.1 Sample Packing and Shipment. At the end of each day, all the collected samples are prepared; the chain-of-custody forms are filled out; and the samples are prepared for shipment. The sample containers are packed with styro-foam inside the shipping shuttles along with the chain-of-custody forms. Frozen blue ice or similar material is also placed in the shuttle in order to keep the samples cold. The shuttle lids are then secured and sealed with a chain-of-custody tag. The shuttles are then shipped to the contract laboratory for analysis. The sample analysis request form is provided directly to the contract laboratory by ESI.

E.5.1.1.3.2 Sample Receipt. Upon receipt of the samples at the contract laboratory, the security of the shuttles (chain-of-custody tags) are checked. Any shuttles that have broken or missing chain-of-custody tags are noted and reported to the facility contact. The following procedures are then followed:

- o The sample and seal information is checked to ensure that they match the chain-of-custody record.
- o The chain-of-custody record is checked for a signature.
- o The request of analysis from ESI's facility contact is checked to determine the analyses requested.
- o A laboratory sample number is assigned.
- o The sample is then stored in a secure area to await analysis.

E.5.1.1.4 Analytical Procedures

The analytical procedures for groundwater quality analyses are summarized in Appendix H [40 CFR 265.92(a)(3)]. These procedures are identical to procedures outlined in EPA Document SW-846. Analytical parameters are discussed in Section E.6.2.

Detection limits equal or exceed (are lower than) detection limits reported in SW-846 and are reported in Appendix H.

E.5.1.1.5 Quality Assurance/Quality Control

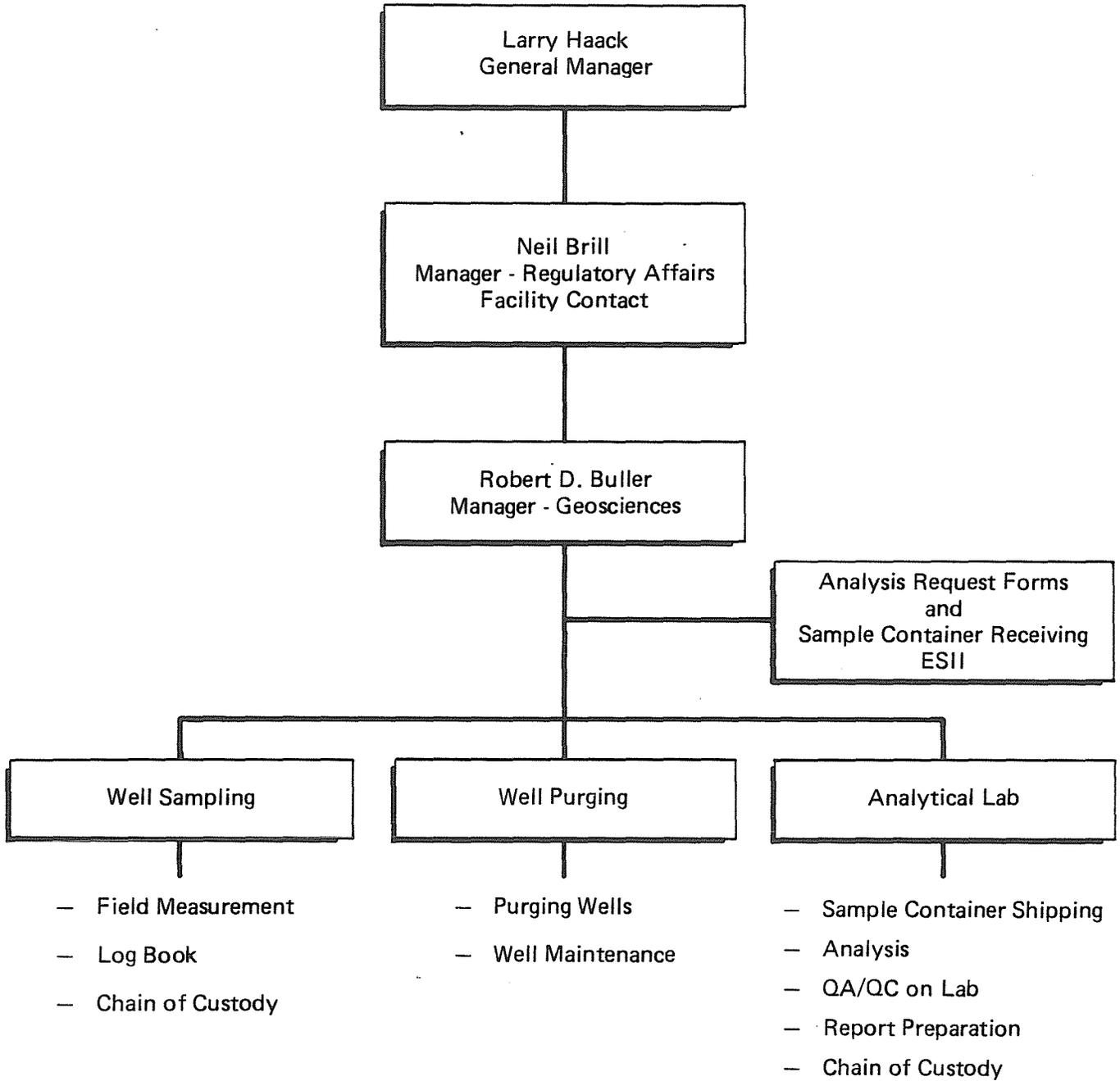
The objective of quality assurance and quality control is to assure that groundwater analytical results truly represent

groundwater chemical and physical composition from groundwater sampling through analytical report preparation.

- o Overall quality assurance will be the responsibility of the Manager of Geosciences of ESI. Figure E.5-1 shows a flow chart that identifies QA/QC activities and responsibilities.
- o In summary, the sampling, analysis, and reporting of data to EPA-Region X is the responsibility of the General Manager of ESII, his designated agents, the ESI Manager of Geosciences, the ESI Manager of Regulatory Affairs, or others as designated by the Senior Vice President of Environmental Affairs. Actual coordination of QA/QC activities is through ESI. ESI is responsible for the QA/QC activities of the samplers, drillers, and analytical laboratories.

Components of the QA/QC program are as follows:

- o **Laboratory:** The analytical laboratory provides all shipping containers, sampling containers and preservatives, chain-of-custody forms, labels, and seals. An example of the laboratory QA/QC procedures is included in Appendix H. That example illustrates the level of detail that laboratory QA/QC reporting achieves. A full laboratory QA/QC report accompanies each data report to EPA-Region X and is kept on file at the facility.
- o **Sample Collection:** QA/QC procedures for sample collection is accomplished by the sampling consultant under the supervision of the ESII facility contact. A standardized field log book is kept



**FIGURE E.5-1  
QUALITY ASSURANCE  
FLOW CHART**



for each sampling event following the format described in the preceding chain-of-custody section. It includes all label and seal numbers and documentations of all QA/QC procedures related to sample collection.

It is standard procedure to include field, lab, and trip blanks, and blind and spiked samples in each sampling event for appropriate parameters.

- Field Blanks. Field blanks consist of a separate set of sample containers, preservatives, and chain-of-custody forms. The containers are opened during routine sampling and sealed upon completion of sampling. The water in the containers (ultrapure water provided by the laboratory) has been exposed to ambient conditions to which the groundwater samples were subjected. Field blanks are used to assess the potential for externally introduced error factors during the sampling event.
  
- Trip blanks. Trip blanks accompany each sealed sample container. They are analyzed for volatiles to assess the level of potential contamination that may have occurred during sample transport.
  
- Lab blanks. Analysis of the water used to prepare the field and trip blank containers is conducted. This water has never left the laboratory. Lab blank data are used to establish the baseline quality of water used in all of the QC/QA blanks.

- Blind and spiked samples. Standard procedures for spiking samples and replicate analyses are covered in Appendix H.
- o QA/QC of Raw Data: Another important component of the QA/QC program is the evaluation of the analytical data as reported by the analytical laboratory. The raw data as reported is reviewed to make sure that it is correct and accurately reported.

The issue of outliers is evaluated using trend line graphical procedures. Trend line graphs have been prepared for all wells for which sufficient data exist for indicator parameters and other chemical constituents at the discretion of ESII.

Additional QA/QC data evaluation procedures are routinely performed and documented in the facility files as needed. These activities include review of all aspects of sampling, analysis, and data reporting.

## E.5.2 MONITORING RESULTS

### E.5.2.1 INTRODUCTION

As required by 40 CFR 265.92 and modified by EPA-Region X on February 29, 1984, samples have been collected each month since January 1984, using the procedures described above. The list of analytical parameters measured during this sampling period is shown in Table E.5-1. All parameters were determined as required by EPA regulations or by specific EPA-Region X order. An exception to this was when sample containers were broken in shipment and some of the analyses could not be performed.

*New Data?*

Table E.5-1  
LIST OF ANALYTICAL PARAMETERS

Parameter	Citation
1. Drinking Water Supply	40 CFR 265.92(b) (1)
2. Groundwater Quality	40 CFR 265.92(b) (2)
3. Contamination Indicator	40 CFR 265.92(b) (3)
4. Metals--Unfiltered	EPA-Region X Order
5. Priority Pollutants and Representative Appendix VIII of Part 261	EPA-Region X Order

All of the data collected from these sampling events are summarized in Appendix F. All analytical results are presented regardless of whether a measureable concentration was detected or not. Appendix J presents well test data collected by the state or by EPA in January 1984. Note that these data contain no backup QA/QC documentation, and ESII could not confirm their accuracy or quality.

*redo*  
Appendix F presents trend plots of the parameters summarized in that appendix for data up to December 1984. These plots were presented in the May 1985 report and have not been updated to include 1985 data. Selected ions are shown on new trend plots for the entire period of record for wells having sufficient data. The advantage of these plots is that the trend of the data can be easily observed. In addition, anomalous values can also be readily identified. For example, the trend plot for barium in Well MW-3 shows consistently low values. However, the barium value in February is significantly higher than all the other data points. It is reasonable to assume that this is an anomalous datum due to sampling or laboratory error since groundwater contamination tends to

move in plumes. Because of this plume phenomenon and the very low groundwater velocity across the site, contaminant spikes are very unlikely. Rather, contaminants would be expected to gradually increase in concentration over several sampling periods if waste constituents were entering the aquifer from the waste disposal units.

*update*  
In examining the trend plots, note that most parameters have some minimal value. In most cases, especially for the organic compounds, these minimal values represent the method detection limit, not necessarily the actual concentration measured or external contributions such as lab and sampling error. These values will be used for the statistical analysis that will be conducted when sufficient data are available for analysis. It does not indicate that the parameter is present at the concentration presented.

#### E.5.2.2 STATISTICAL ANALYSIS

*Bob  
Redo? yes*

Federal regulation 40 CFR 265.93(b) requires that data collected from a Groundwater Monitoring Program be analyzed statistically using the Cochran's Approximation to the Behrens-Fisher Student's t-test. In general, these methods are intended to provide early warning of potential contamination appearing in the monitoring wells. For this type of analysis, the most current data are compared to a body of background data. If statistically significant differences occur, then additional steps are taken to investigate and confirm or reject the premise that contamination is appearing in the wells.

A large body of statistical experts have discovered that the Student's t-test typically triggers false positives in groundwater monitoring programs. This issue is presently under

review by EPA's Science Advisory Board. Because of the problems with this test, more appropriate statistical methods are proposed in the 264 Subpart F Groundwater Monitoring Program described in Section E.6.

As described in the Aquifer Identification section, two aquifers underlie the site. While the data collected for the upgradient and downgradient wells do represent the water from the uppermost aquifer in those wells, they do not all represent water in the same aquifer regime. Monitoring Well MW-6 is an upgradient well. An examination of the flow net presented in Figure E.4-9 shows that MW-5 should also be an upgradient well in that it should be unaffected by any site activities. However, the aquifer monitored by MW-5 and MW-6 lies below the aquifer in downgradient Wells MW-1, MW-2, and MW-3. Well MW-4 probably pulls water from both upper and lower aquifers. Because there are insufficient data for upgradient and downgradient wells in the same aquifer, a meaningful statistical analysis cannot be performed at this time. Additional monitoring wells have been added and will soon provide enough background data for each aquifer for the required statistical tests.

BOT513/013

E.6 DETECTION MONITORING PROGRAM

New text

E.6.1 INTRODUCTION

As described in detail in Section E.4 of this report, the ESII Site B is underlain by two independent aquifers, described as the upper and lower aquifers. The upper aquifer material is only saturated beneath the northern half of the site and is the uppermost aquifer in that area.

Across the southern half of the site, the upper aquifer material is not saturated. Beneath the southern half of the site, the lower aquifer is the "uppermost" aquifer and, consequently, the Detection Monitoring Program will incorporate discussions of wells and sampling of both upper and lower aquifers.

The 40 CFR 264 Subpart F regulations specify that a groundwater monitoring program be established for the uppermost aquifer and any lower aquifers that are hydraulically connected to the uppermost aquifer beneath the waste disposal facility. It has been established in the course of the site characterization that the upper and lower aquifers beneath the facility are not hydraulically interconnected. The documentation to support this conclusion is provided in previous sections.

The basis for this interpretation includes the following:

1. Each of the two aquifers has its own unique water chemistry and shows no evidence of intermixing.
2. The piezometric water level in each of the aquifers is different. This would not be the case if the two aquifers were connected.

3. The rate and direction of groundwater flow is different for each aquifer.
4. The geologic material (dense clay) between the two aquifers is thick enough and of low enough permeability to prevent hydraulic interconnection between the two aquifers.
5. The moisture content tests of the dense clay between the two aquifers indicate that the clay may be below saturation for at least part of its thickness.

It is beneficial to clarify the intent of the two-aquifer monitoring program: The two aquifers are each being monitored because they are each classified as the uppermost aquifer beneath separate portions of the site. The lateral extent of where each of the two water-bearing zones is the uppermost aquifer beneath the site, as seen on Figures 4.3 and 4.8. These figures show which existing and proposed disposal units are underlain by each of the two uppermost aquifers. Figure 4.8 shows that the lower water-bearing zone is the uppermost aquifer beneath all or part of the following disposal units:

- Future Trench 14
- Future Trench 15
- Future PCB-6
- Active PCB-4
- Future Evaporation Pond Area
- Future PCB-5
- Miscellaneous Pre-RCRA Buried Waste Areas

All remaining disposal units are located over the upper water-bearing zone or aquifer. In order to maintain consistency in referencing, the aquifers will be referred to as

the upper aquifer and the lower aquifer even though, as stated above, the upper aquifer is the uppermost aquifer beneath the northern half of the site and the lower aquifer is the uppermost aquifer beneath the southern half of the site.

Regulation 40 CFR 264.91 specifies the conditions that must be met by the owner/operator to select a groundwater monitoring program. If hazardous constituents are detected in the uppermost aquifer at the point of compliance and are reasonably expected to be in or derived from waste contained in the regulated units, the owner must institute a Compliance Monitoring Program. If the groundwater protection standard under 40 CFR 264.92 is exceeded, or if concentration limits are exceeded between the point of compliance and the property boundary, a Corrective Action Program is required under 40 CFR 264.100. In all other cases, a Detection Monitoring Program under 40 CFR 264.98 is appropriate.

To select the appropriate monitoring program for the ESII facility, it is necessary to assess which of the conditions defined above are applicable. Subpart F Rules and Regulations state that for compliance monitoring to be instituted, the monitoring well analytical data must indicate that any hazardous constituents detected are "...reasonably expected to be...derived from a regulated unit" [40 CFR 264.91(a)(1)]. In the case of the ESII facility, several hazardous constituents have been detected in the point of compliance monitoring wells that are monitored under the 40 CFR 265 (Interim Status) groundwater monitoring program. This program is described in the Water Quality section of this document (Section E.5), and the analytical data base is found in Appendix F. The judgment of ESII is that the hazardous constituents detected are not derived from regulated units; therefore, the appropriate monitoring program for this facility is a Detection Monitoring Program.

The evaluation of these data is covered in the Water Quality section, but several examples are covered here to demonstrate the basis for this conclusion. The hazardous constituent, 1,1,1-trichloroethane, was detected in Wells MW-1, MW-3, and MW-5 early in 1984. However, evaluation of the well construction materials revealed that these three wells had pumps installed that were not of all-stainless-steel materials. Furthermore, an evaluation of the direction of groundwater flow beneath this facility indicates that there have not been past or present hazardous waste disposal activities upgradient from MW-5, and for that reason, MW-5 is not truly a downgradient well under past or present operational conditions. The pumps in Wells MW-1, MW-3, and MW-5 were replaced with all-stainless-steel pumps in January 1985, and the analytical results through March 1985 indicate that this problem has been eliminated.

A commonly accepted fact in the scientific community is that phthalates are a ubiquitous class of compounds that are readily leached by water from PVC well casings and other plasticized materials. EPA-Region X personnel have stated such in writing with regard to the groundwater monitoring results from this facility. Phthalates have been found in all or most of the monitoring wells, both upgradient and downgradient, on several occasions. This is another example of a hazardous constituent found in groundwater samples that was not derived from a regulated unit.

Another hazardous constituent routinely found in the monitoring well data is methylene chloride. Review of quality assurance control/quality data (trip blanks, field blanks, and batch blanks) and discussions with the contractor laboratory indicate that this constituent is a commonly found laboratory contaminant and is not derived from the regulated unit.

In summary, an evaluation of the hazardous constituents found in the monitoring data base, some of which are described above, indicates that they are not derived from the regulated units and that compliance monitoring is not appropriate for this facility. A corrective action program is also not appropriate for the following reasons:

1. No groundwater protection standard has been established for this facility; therefore, it cannot have been exceeded.
2. Concentration limits have not been established for this facility; therefore, they cannot have been exceeded.
3. If compliance monitoring is not appropriate, then corrective action is also not appropriate because compliance monitoring would necessarily be instituted prior to the need for corrective action.

For the reasons enumerated and described above, a Detection Monitoring Program is appropriate for this facility.

#### E.6.2 ESTABLISHMENT OF MONITORING PARAMETERS

As required under 40 CFR 264.98(a), ESII will establish a list of parameters to be monitored that provide a reliable indication of the presence of hazardous constituents in groundwater. These parameters will include indicator parameters and hazardous waste constituents (or their reaction products).

As described elsewhere in this permit application, the ESII facility is a full-service hazardous waste treatment and disposal facility. As a result of past disposal practices,

it already contains a broad spectrum of hazardous wastes and, therefore, it is not reasonable or appropriate to categorically eliminate any one waste type from the list of parameters to be monitored.

If, in fact, it is assumed that the facility contains a full spectrum of hazardous wastes, it is most appropriate to select monitoring parameters that would either: (1) provide full coverage of all waste constituents and reaction products, or (2) provide a reliable indication of the presence of any waste constituents or reaction products.

In the Federal Register (Volume 49, Number 191/Monday, October 1, 1984/Proposed Rules), the Environmental Protection Agency has addressed the inordinate cost and inappropriateness of requiring that all Part 261 Appendix VIII parameters be routinely included in a 40 CFR 264 Detection Monitoring Program. EPA has proposed a screening program called a Hierarchical Analysis Protocol (HAP), which may be employed as an alternative to the full Appendix VIII list under certain circumstances. Unfortunately, the proposed HAP screening program is largely untested and authoritative sources familiar with the implementation of the HAP screening program have found that it invariably results in a false positive trigger of all or part of the Appendix VIII testing program.

As an alternative to the HAP screening program, ESII proposes the following procedures to establish a list of monitoring parameters for the Detection Monitoring Program:

1. ESII will analyze for the four commonly accepted indicator parameters, total organic halides (TOX), total organic carbon (TOC), pH, and specific conductance, on a quarterly schedule in all RCRA monitoring wells. These four indicator parameters

are appropriate because TOX and TOC are indicators for the organic wastes disposed of at the facility, and pH and specific conductance are indicators of the acid wastes and other inorganic wastes disposed of at the facility. In addition, TOX is used as an indicator parameter because evaluation of existing data shows it to be of relatively low concentration in background water samples and would therefore be sensitive to small changes should contaminants migrate to the point of compliance. The proposed quarterly monitoring is more frequent than the required minimum (semi-annual) sampling frequency specified in 40 CFR 264.98(d). This testing program will provide for continuity with the existing data base and will provide a significant data pool for statistical analysis of data.

2. ESII will analyze for the entire 40 CFR 261 Appendix VIII parameter list (that portion of the list than can be reasonably accomplished based on the most recently accepted analytical protocols) on an annual basis in all RCRA monitoring well samples. The rationale for this is that: (a) no reasonably accurate screening technique has been developed to preclude the necessity of analyzing for the full Appendix VIII list; (b) because of the wide range of waste constituents disposed of at the facility, there is no list of indicator parameters that would guarantee that all potential waste contaminants migrating to the point of compliance would be detected; and (c) the groundwater velocities for the upper aquifer determined during the site characterization study were conservatively calculated at 2 to 87 feet per year along the eastern boundary and average 37 feet per year across

the site (see Subsection E.4.2.4.2). The velocities in the lower aquifer range from 3 to 13 feet per year and the average is 7 feet per year. At this rate, the spatial interval between Appendix VIII annual analyses would be so small that no Appendix VIII parameters, if detected, could escape from the property before compliance monitoring and/or corrective action was implemented, if one was deemed necessary.

The advantage of monitoring for the Appendix VIII list is that there is no need to give special consideration to waste types, quantities, concentrations, or their mobility, stability, or persistence. Furthermore, this makes it unnecessary to rely on the indicator parameters measured on a quarterly basis, except as an "early warning" system to act as a trigger for additional Appendix VIII testing should it become necessary.

Inherent in this proposed list and analytical schedule is the concept that the four indicator parameters sampled quarterly (TOX, TOC, pH, and Specific Conductance) would be the basis for the statistical analysis performed according to 40 CFR 264.97(h)(1)(i) and would be the only parameters for which the establishment of background values for statistical purposes would be required. Obviously, statistical analysis, as specified in 40 CFR 264.97(h)(1)(i), cannot be performed on the Appendix VIII list, and any comparison of Appendix VIII parameters between upgradient and downgradient wells, or within each well over time, would be done using a non-statistical methodology, such as trend-line analysis or other graphical techniques.

### E.6.3 ESTABLISHMENT OF BACKGROUND VALUES

As required under 40 CFR 264.98(c), ESII will establish a background value for each monitoring parameter or constituent specified in the permit, including indicator parameters, waste constituents, or reaction products that provide a reasonable indication of the presence of hazardous constituents in groundwater. Background values will be based on data from quarterly sampling of wells upgradient from the waste management area in both the upper and lower aquifers (see introductory paragraphs to this section and Section E.4.2.2 for aquifer descriptions) for one year, as required under 40 CFR 264.97(g)(1).

In addition to establishing background values based on the collection of quarterly samples for one year, ESII will calculate a rolling annual average, incorporating data collected subsequent to the first year of sampling under 40 CFR 264 Subpart F. The purpose of these calculations is to determine whether seasonality or naturally occurring fluctuations in water chemistry are affecting the establishment of representative background values. If it is determined that such natural fluctuations are having a significant impact on background values, ESII will prepare a demonstration to EPA showing why background values based on a time period other than the first year should be used for performing the statistical analyses under 40 CFR 264.97(h).

It is proposed that the wells used to establish background values for this Detection Monitoring Program include Wells MW-13 and MW-6 for the lower aquifer and Wells MW-15 and MW-16 for the upper aquifer, as described in Subsection E.6.5.3. Lower aquifer Wells MW-6 and MW-13 are obviously upgradient of the facility based on results of the Site Characterization Report presented in the permit application. Existing Wells MW-15 and MW-16 are in upgradient positions for the upper aquifer.

In developing background data from the upgradient wells, the process of collecting data will commence as soon as the proposed detection monitoring plan is given approval by EPA-Region X. Interim status groundwater monitoring data (40 CFR 265) are not appropriate for establishing background values for this proposed program for the following reasons:

1. Under interim status regulations, the data base of indicator parameters is developed by splitting one sample from each upgradient well into four portions prior to performing an analysis. Under 40 CFR 264 regulations, the owner or operator must take a minimum of one sample from each well and a minimum of four samples from the entire system used to determine background groundwater quality each time the system is sampled [40 CFR 264.97(g)(4)]. Therefore, the interim status groundwater monitoring system does not conform to the 264 regulations for establishing background values because there are only two samples from each of the two uppermost aquifers.
2. The sampling parameters proposed for the detection monitoring network differ from the parameters included in the Interim Status monitoring program.

No gap in the Detection Monitoring Programs from 40 CFR 265 to the implementation of the 40 CFR 264 program are foreseen because:

- a. It is anticipated that there will be a temporary significant overlap between the two programs while the background data for the 264 program are being collected. Therefore, if any indications of constituent migration

appear during that time, they will be dealt with under the interim status regulations.

- b. It is anticipated that the collection of background data can commence prior to the issuance of the Part B permit once EPA approval of the Detection Monitoring Program is received.

The establishment of background values will be based on the collection of data from quarterly sampling of Wells MW-13, MW-6, MW-15, and MW-16 for one year as required in 40 CFR 264.97(g)(1). To accomplish this, four separate samples will be collected from each of the four upgradient wells on a quarterly basis. This will result in a data pool after this one-year period of 64 individual data points; 32 data points for each aquifer to be used for statistical comparison purposes for each of the selected indicator parameters. This process will continue throughout the duration of the Detection Monitoring Program, resulting in a pool of background data that expands on a quarterly basis.

The method for establishing background values for the four indicator parameters is to calculate on a quarterly basis the mean, the median, the coefficient of variation, and the standard deviation. These values are necessary to perform the statistical comparisons required under 40 CFR 264.98(c)(2), which references 40 CFR 264.97(h). The statistical parameters identified above will not only provide the basis for statistical analysis under 40 CFR 264.98(c)(2), the Student's t-test, but also the alternate statistical procedures allowed under 40 CFR 264.97(h)(1)(ii).

Pursuant to 40 CFR 264.98(d), the analytical strategy developed in this section will also be followed during the site's

closure period except that sampling will be conducted only semi-annually.

#### E.6.4 ALTERNATE CONCENTRATION LIMITS

The groundwater protection standard (GWPS) under Subpart F (40 CFR 264.92) requires the Regional Administrator to establish in the facility permit for each hazardous constituent entering the groundwater from a regulated unit, a concentration limit beyond which degradation of groundwater quality will not be allowed. The concentration limits determine when corrective action is required.

There are three possible concentration levels that can be used to establish the GWPS:

1. Background levels of the hazardous constituents
2. Maximum concentration limits listed in Table 1 of Section 264.94(a) of the regulations
3. Alternate concentration limits (ACL)

The first two levels are established in the facility permit unless the facility owner or operator applies for an ACL.

To obtain an ACL, a permit applicant must demonstrate that the hazardous constituents detected in the groundwater will not pose a substantial present or potential hazard to human health or the environment at the ACL levels. ACLs are granted through the permit process under Parts 264 and 270 and are established in the context of the facility GWPS. It is the intent of ESII to have the EPA establish ACLs in the GWPS for this facility in the Part B permit based on an anticipated proposal from ESII.

The factors that are used to evaluate ACL requests, or demonstrations, are listed in Section 264.94(b) of the regulation. These factors are:

1. Potential adverse effects on groundwater quality considering:
  - o The physical and chemical characteristics of the waste in the regulated unit, including its potential for migration
  - o The hydrogeological characteristics of the facility and surrounding land
  - o The quantity of groundwater and the direction of the groundwater flow
  - o The proximity and withdrawal rates of groundwater users
  - o The current and future uses of groundwater in the area
  - o The existing quality of groundwater, including other sources of contamination and their cumulative impact on the groundwater quality
  - o The potential for health risks caused by human exposure to waste constituents
  - o The potential for damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents
  - o The persistence and permanence of the potential adverse effects

2. Potential adverse effects on hydraulically connected surface water quality, considering:

- o The volume and physical and chemical characteristics of the waste in the regulated unit
- o The hydrogeological characteristics of the facility and surrounding land
- o The quantity and quality of groundwater and the direction of groundwater flow
- o The patterns of rainfall in the region
- o The proximity of the regulated unit to surface waters
- o The current and future uses of surface waters in the area and any water quality standards established for those surface waters
- o The existing quality of surface water, including other sources of contamination and the cumulative impact on surface-water quality
- o The potential for health risks caused by human exposure to waste constituents
- o The potential for damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents
- o The persistence and permanence of the potential adverse effects

Information on each of these criteria is not required in every ACL demonstration because each demonstration requires different types and amounts of information, depending on the site-specific characteristics.

Guidance on the applicability and preparation of ACL demonstrations has been prepared by EPA's Office of Solid Waste (Draft, June 1985). Using this guidance, ESII has determined that ACLs for select monitoring parameters are appropriate for inclusion in the GWPS to be established by EPA for this facility.

The intent of the regulation is to establish GWPS that limit the amount of groundwater contamination that can be allowed without endangering public health or the environment. Alternate concentration limits can be established only after the applicant has performed a risk assessment to show that concentrations of specific chemical constituents detected at the point of compliance in the facility's groundwater monitoring network will not adversely affect public health or the environment. The EPA guidance on ACLs is currently in draft form and case histories documented by EPA have just recently been published. Because of the magnitude of effort involved in the risk assessment and the relative newness of ACL guidance, specific ACL documentation is now being prepared and will be included in the Part B permit for this facility prior to its final issuance.

#### E.6.5 GROUNDWATER MONITORING SUMMARY

##### E.6.5.1 AQUIFER SUMMARY

The ESII site is underlain by two aquifers. The upper aquifer section is unsaturated across the southern half of the site and consequently the lower aquifer is the "uppermost" aquifer over the southern portions of the site.

The lower aquifer is developed in a series of thin, discrete, very fine sand to silty sand seams contained in a silt sequence within the Glenns Ferry Formation. Although the silt section is typically 30 to 40 feet thick, the actual cumulative thickness of the thin sandbeds and seams is only about 4 feet.

Across the eastern side of the site, the lower aquifer contains several silty sandbeds from 3 inches to as much as a foot thick. These beds produce less than one gallon per minute. A single one-foot bed near the top of the aquifer apparently produces the majority of the water.

From east to west the lower aquifer sandbeds become thinner and siltier. Along the west side of the site the lower aquifer is comprised of 1/16- to 2-inch-thick sand seams spread over 15 feet of the 30- to 40-foot-thick bedded silts and clays making up the lower aquifer section.

Groundwater in the lower aquifer is moving from southwest to east-northeast in a fairly uniform pattern. Gradients are steepest in the southwest corner of the site and become less steep and more easterly across the site. Gradients range from .019 to .038 foot/foot.

Hydraulic conductivities for the lower aquifer range from 0.06 to 0.83 foot per day ( $3.5 \times 10^{-5}$  cm/sec to  $2.2 \times 10^{-4}$  cm/sec). Groundwater velocities range from 3 to 13 feet per year and average about 7 feet per year.

A 20- to 30-foot-thick massive clay separates the upper and lower aquifers. The clay has vertical permeabilities from  $10^{-6}$  to  $10^{-8}$  cm/sec. Portions of the interclay are not saturated. The clay is continuous across the site, as evidenced by core logs and geophysical logs.

The upper aquifer consists of discrete, thin sandbeds in a silty sequence of the Glens Ferry similar to the lower aquifer. Across the eastern side of the site the upper aquifer consists of four to five 3-inch to one-foot fine, silty sandbeds present within the 80- to 90-foot-thick bedded sand, silt, and clay sequence making up the upper aquifer section.

The upper aquifer section is continuous across the site, but because of the structural dip of the formations, the individual sandbeds emerge out of the water and are not saturated over the southern half of the site. This line of emergence is an arc that runs roughly east-west and passes south of Silo 1. From south to north, increasing numbers of sandbeds become saturated and the potentiometric surface rises up through the aquifer section. Consequently, the saturated thickness of the aquifer ranges from zero feet at its southern limit to approximately 60 feet along the northern site boundary.

Along the northern and northwestern portions of the site, the number of sandbeds and their thickness increase, and the upper aquifer becomes increasingly sandy. Wells in the upper aquifer in the northwest corner of the site produce more than 5 gallons per minute. Sand content and well yields decrease to the east and south. Most upper aquifer wells yield less than one gpm.

Water in the upper aquifer is flowing into the site from the west-northwest corner. Because of high transmissivities of the aquifer in this area, the gradients are low (.006 to .0095 foot/foot). From west to east across the site the gradients gradually increase, apparently reflecting the decreasing transmissivity due to less sand. Along the eastern portions of the site the gradients approach .03 foot/foot.

Hydraulic conductivities of the upper aquifer range from  $1.2 \times 10^{-3}$  cm/sec to  $9.9 \times 10^{-4}$  cm/sec and averages  $8.6 \times 10^{-4}$  cm/sec.

Groundwater velocities reflect the effect of the low gradients in the northwest corner where, even though the hydraulic conductivities are high, the velocities are low, ranging from one to 33 feet per year. The highest velocities occur in the northeast corner where thin but significant sands and high gradients combine to produce velocities in the 82 feet per year range. The average velocity in the upper aquifer across the entire site is about 37 feet per year.

In summary, the ESII Site B overlies two discrete aquifers. The uppermost aquifer is unsaturated over the southern half of the site. The lower aquifer is saturated beneath the entire site, but is separated from the upper aquifer by 30 feet of tight clay that has low vertical permeability and is not saturated. Both aquifers consist of thin, discrete, fine silty sand in the predominantly clay matrix of the Glens Ferry Formation. The lower aquifer is confined above and below by tight clays; the upper aquifer is confined below by tight clays and above by bedded silts and clays within the unsaturated portion of the upper aquifer section.

Pursuant to 40 CFR 264.98(b) and 40 CFR 264.98(c)(3), a monitoring well network has been installed at the ESII site. This network is described below, and pertinent data regarding well construction are included in Appendix B.

#### E.6.5.2 DOWNGRADIENT WELLS [40 CFR 264.98(b)]

As described in Section E.4.2.2, Aquifer Descriptions, the uppermost aquifer beneath the site actually consists of two

hydraulically isolated aquifers. The uppermost aquifer beneath the northern portion of the site, described as the "upper aquifer," flows almost due east (with a slight south-east vector) at an average rate of approximately 33 feet per year. Under the southern portion of the site, the "upper aquifer" is unsaturated. Therefore, the uppermost aquifer is the unit described as the "second aquifer" or the "lower aquifer," which flows at an average rate of approximately 7 feet per year in an east-southeasterly direction. This lower aquifer is saturated everywhere under the site, but is considered the uppermost aquifer only beneath the southern portion of the site where the upper aquifer is unsaturated.

The result of having two distinct units as the uppermost aquifer, depending on where the point of compliance groundwater is monitored, complicates the placement of both upgradient and downgradient monitoring wells. Although the vast majority of past and existing disposal activities are located over the portion of the site where the upper aquifer is saturated (and is, therefore, the uppermost aquifer), a monitoring well network is proposed that includes both upper and lower aquifers. This will allow the continuity of monitoring the second aquifer in those areas where disposal activities occur over the "lower aquifer," such as Trench PCB-4, and for future proposed disposal activities in the southern portion of the site.

The locations of all proposed downgradient monitoring wells are shown on Figure E.6-1. This figure shows that Wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-10, MW-11, MW-12, MW-21, MW-24, and MW-25 are designated as proposed downgradient monitoring wells. Using this configuration, Wells MW-1, MW-2, MW-3, MW-4, MW-10, and MW-11, would be downgradient wells for the "upper aquifer" (the uppermost aquifer in the northern portion of the site) and Wells MW-5, MW-12, MW-21, MW-24, and

W-25 would be downgradient wells in the "lower aquifer" throughout the entire site. The total number of proposed downgradient monitoring wells is 11 (6 in the "upper aquifer" and 5 in the "lower aquifer").

Figure E.6-1 shows that MW-1, MW-2, MW-3, MW-4, and MW-5 are set back by approximately 80 feet from the edge of the waste management area. These wells were among the first to be installed as part of the Interim Status groundwater monitoring network under 40 CFR 265 Subpart F and were set back from the edge of the waste management area because of uncertainties in the exact extent of waste disposal activities conducted by previous owners.

Wells MW-10, MW-11, MW-12, MW-21, MW-24, and MW-25 were installed after it was confirmed that the limits of the waste disposal areas used by the previous owner did not extend past the point of compliance established for this site. There are several reasons why MW-1, MW-2, MW-3, MW-4, and MW-5 are included in the proposed point of compliance monitoring well network required by 40 CFR 264.98:

1. The wells have been sampled monthly since well installation, approximately 24 months ago. This represents a large water quality data base useful in determining any statistical differences between upgradient and downgradient wells.
2. The wells complement the other point of compliance wells by establishing a tighter grid of wells to ensure that if waste constituents were to leave the site, they would not go undetected.
3. The thick vadose zone present at this site argues for a point of compliance set back from the limits



of the waste management boundary so that any contaminants leaking from the site would be detected in the groundwater in the monitoring wells at these locations.

All of the downgradient monitoring wells are existing wells that were used in the characterization of the site and/or to provide the Interim Status monitoring data. As shown on Figures E.4-4 and E.4-5, all of the wells are installed at the correct depth to monitor the uppermost aquifer at the site, in accordance with 40 CFR 264.97(a).

The geologic and geophysical logs indicate that the uppermost aquifer consists of finely bedded silty sand seams and sandy clay. The overall uniformity of flow that would occur through this type of matrix and the number and location of the downgradient wells will assure that samples representative of the groundwater passing the point of compliance will be collected in accordance with 40 CFR 264.97(a)(2).

In compliance with 40 CFR 264.97(c), the wells were installed to ensure the integrity of the monitoring wells and to prevent surface leakage down the annulus. Steel surface casing was driven to the top of competent clay or clayey strata, typically 140 feet. An air rotary hole was drilled to total depth, and the well was cased using threaded flush joint Schedule 40 PVC casing. No solvents were used. PVC well screen with 0.010-inch manufactured slots and a clean silica sand filter pack were installed adjacent to the aquifer material. A short section of blank PVC casing extends below the well screen to provide a silt sump to help reduce screen silting problems. The well construction materials were selected to provide suitable long-term performance within the physical and chemical environment encountered in the subsurface at the site.

In all downgradient upper aquifer monitoring wells, the well screen extends slightly above the seasonal high potentiometric surface to ensure that any floating contaminants may enter the well and be detected. The sand pack extends slightly above the top of the screen in all wells. Since the lower aquifer is confined, the potentiometric surface rises well above the aquifer. Well screens in the lower aquifer wells are located to sample water moving in the top of the lower aquifer.

The annulus between the surface casing and borehole wall was filled with dry bentonite as the casing was advanced, and the annulus above the sand pack was filled with dry granulated bentonite. A cement surface seal was placed in the top 10 feet.

All wells are equipped with bottom and top caps and a locking security cover. Steel guard posts are set around all wells. Details of the construction of these wells are provided in Tables E.3-1 and E.3-2 and in Appendix B.

#### E.6.5.3 BACKGROUND MONITORING WELLS [40 CFR 264.98(c)(3)]

As discussed previously and as shown on Figure E.4-9 and in Appendix E, the lower aquifer flows from southwest to east-northeast beneath the entire site. In the upper aquifer, groundwater generally flows from west-northwest to east beneath the northern half of the site. Along the north and south boundary, flow in the upper aquifer is parallel to or slightly into the site.

As presented in Section E.4.2, Site Hydrogeology, the site has two distinct hydrologic regimes (aquifers). To establish meaningful background characterization of the groundwaters moving beneath the site, background water will be

sampled at two points across the upgradient side of the site in each aquifer.

Pursuant to the above statute and in compliance with 40 CFR 264.97(a)(1), (b), and (c), four monitoring wells will be used to determine background water quality at the ESII site. The wells that will be used to establish background water quality, as shown on Figure E.6-1, are MW-13, MW-6, MW-15, and MW-16.

Wells MW-13 and MW-6 are existing monitoring wells in the lower aquifer. They were installed for Interim Status monitoring and have been sampled monthly since installation. Wells MW-15 and MW-16 are positioned in the upper aquifer. Well MW-15 was incorporated into the Interim Status monitoring well program in April 1985 and has been sampled on a monthly basis. Well MW-16 was incorporated with the Interim Status system in September 1985.

ESII has proposed that a future Trench 14 will be constructed along the southern property line. Prior to construction, Wells MW-5 and MW-12 will be activated along the downgradient point of compliance. These wells will be activated at least one year prior to the deposition of water in Trench 14. Wells MW-5 and MW-12 will not be activated prior to one year before Trench 14 becomes active because they are not downgradient from any existing regulated disposal units.

Wells MW-16 and MW-15 will provide background data for the upper aquifer where it becomes saturated over the central and northern portions of the site.

As described in the previous section, existing well construction methods satisfy 40 CFR 264.97(a) and (c). Wells MW-13,

MW-6, MW-15, and MW-16 were constructed in a similar fashion and consequently also comply with the statute.

E.6.6 ANNUAL DETERMINATION OF GROUNDWATER FLOW RATE AND DIRECTION [40 CFR 264.98(e)]

Pursuant to 40 CFR 264.97(f), water level elevations are determined before each well is sampled. The water level data collected before the November quarterly sampling event will be used to prepare updated potentiometric surface maps similar to the ones presented as Figures E.4-8 and E.4-9.

Once the potentiometric surface map has been prepared, representative flow lines will be drawn to show the direction of groundwater flow. Figures E.4-8 and E.4-9 of this document will be used as examples in the preparation of this map.

Groundwater flow velocity will be calculated using Darcy's Law:

$$V = KI/n$$

Where:

- V = Average linear velocity (L/T)
- K = Hydraulic conductivity (L/T)
- I = Hydraulic gradient (L/L)
- n = Effective porosity (%)

Hydraulic conductivities determined for the location at each downgradient monitoring well presented in Table E.4-7 will be used. The hydraulic gradients will be determined from the new water level data. The gradient at each well will be determined. An effective porosity of 0.43 will be used for the reasons specified in Section E.4.2.3.4 of this report. A velocity will be calculated for each downgradient monitoring well.

Pursuant to 40 CFR 264.98(e) the potentiometric map, flow directions, and groundwater velocities will be updated once each year.

#### E.6.7 VADOSE ZONE MONITORING

##### E.6.7.1 DISCUSSION

At the ESII site, saturated soil materials exist at depths ranging from 140 to 200 feet below the site, and as shown on the geologic cross sections on Figures E.4-1, E.4-4, and E.4-5, Plate E.4-1, and the drill logs in Appendix B, the upper 200 feet of soils underlying the site contains many discontinuous sand, silt, and clay beds.

The laterally changing stratigraphic sequences in the upper 200 feet make it difficult to predict exactly when or where a potential hazardous constituent may reach the groundwater. The stratigraphic units in the vadose zone can, in general, be assumed to conform to the overall attitude of the parent formation. On the basis of the core drilling conducted during the site characterization, sand and clay beds in the upper 120 feet of the Glenns Ferry Formation were determined to dip to the north-northeast at 2 to 3.4 degrees.

A freshwater limestone encountered in Coreholes D-21, D-22, and D-23 at about 140 feet (Figure E.4-2 and Plate E.4-1) yielded a dip of 3.4 degrees to the north-northeast. Confirmatory checks on the dip came from the top of the clay that underlies the uppermost aquifer shown on Figures E.4-2, E.4-4, and E.4-5. An average dip of 2.3 degrees to the north was determined for the intermediate clay separating the upper and lower aquifers. From these independent checks, it can be assumed that the general dip of sedimentary units in the vadose zone is 2 to 4 degrees to the north-northeast.

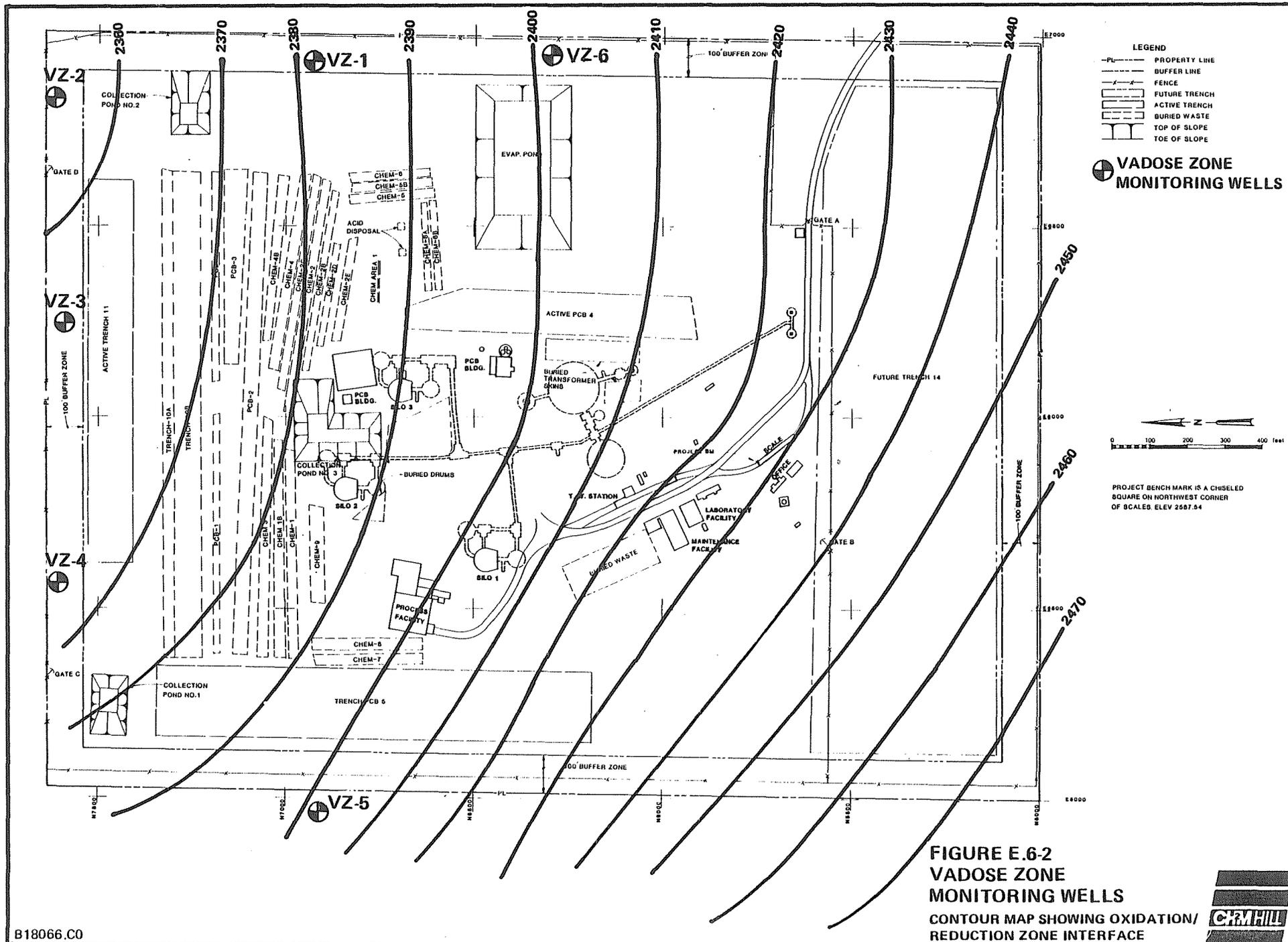
The confining silts and clays overlying the upper aquifer are the most important stratigraphic units beneath the site when considering vadose zone monitoring. This clayey section, however, does not have a sharp upper contact as it grades downward from a clayey sand with clay interbeds to thickly bedded clays and silt without appreciable sand. Within this section the brown to blue-gray (oxidation/reduction) color change occurs. The first groundwater saturated sands were found as much as 100 feet below this color change.

The color change is not a sharp line as it is dependent on moisture content and permeability of the tight clays within the zone. It occurs over 5 to 10 feet of section. The color change is, however, very distinct and consequently is easy to detect during air rotary drilling. Thus, the oxidation/reduction surface, as shown on Figure E.6-2, is well defined but has been generalized somewhat to show approximate trends. Although found at slightly different horizons in the confining clayey zone across the site, the attitude of the oxidation/reduction zone provides a useful guide to the structural dip of the strata in the vadose zone and of the top of the upper confining beds.

Figure E.6-2 presents a contour map drawn for the top of the blue clay. As can be seen from this figure, the blue clay slopes to the north and apparently has a slight bowl shape opening to the north. Other beds above and below this blue clay generally parallel this shape.

#### E.6.7.2 VADOSE MONITORING PLAN

Several methods of monitoring the vadose zone at hazardous waste disposal facilities are described in literature (Everett et al., 1983). Many of the methods, however, are



either adaptations of standard shallow soil engineering technology, experimental in nature, or were installed during construction of disposal facilities. At the ESII site, the thickness of the vadose zone and the fact that this is an active site limit the options to several proven methods: vacuum lysimeters, soil tensiometers, and neutron (moisture) logging.

Neutron logging in six vadose monitoring wells will be conducted at the site. The advantages neutron logging has over the other methods are simplicity in theory and operation, reliable field installations, and detection of moisture increases over the entire unsaturated interval.

On the basis of the structural setting described above, six vadose monitoring wells will be located along the northeast, north, and northwest sides of the site. The wells will penetrate slightly into the confining beds overlying the upper aquifer. The wells will be located downdip of the site and nearest disposal areas as determined by the surface of the blue clay shown on Figure E.6-2 and from the dips determined on the limestone beds.

Well VZ-5 will be located outside of the northwest corner of the site. This well may be used to establish background moisture changes, since it is somewhat updip of the disposal areas on the west side of the site. All wells are shown on Figure E.6-2.

Vadose wells will consist of 4-inch maximum diameter steel well casing installed to within 10 feet of the top of the water table. Thin-wall aluminum casing is recommended in the literature, but this is impractical because of the required depth, potential for galvanic reaction, and short-lived wells. PVC has large numbers of chlorine atoms that

effectively block neutrons, whereas steel casing is nearly transparent to neutrons. The casing will be perforated to allow sampling of any fluid that reaches saturated conditions near the well.

Split spoon samples, taken on 5-foot intervals during well drilling, will be sealed and transported to a soils lab for moisture content determination. This information will be used to establish general moisture profiles against which the neutron logs can be calibrated.

The neutron logging wells will have a minimum disturbed envelope around them. The envelope should offer uniform near-well conditions for the neutron log to be most effective and sensitive to formational moisture content changes. Hollow stem auger is the preferred drilling and installation method and would yield good samples. The depth to which these wells must be installed and the size of the neutron logging tools may preclude this method. Air rotary with driven casing is also a possibility. The actual well installation procedures will be finalized during the installation.

If drilling an oversize hole is necessary, clean, fine sand will be placed around the well to provide uniform near-well moisture conditions for the neutron logs. If sand pack material is installed around the casing, it may create a potential pathway for rapid vertical migration if contaminants reach the well. Periodic bentonite plugs will be placed in the annulus to prevent this from happening.

Neutron logs will be run (going down and coming out of the well) on all vadose wells twice a month for the first 2 months to establish repeatability and baseline conditions. After

baseline conditions have been established, the wells will be logged every 6 months.

If a significant increase in moisture content is detected in the routine monitoring, a second log will be run as soon as practical, and a third set of logs will be run in 2 weeks. A "significant increase" will be defined by comparison of background and downgradient moisture levels and ranges. If the elevated levels are confirmed, a program will be developed to obtain a soil sample from that horizon. It is anticipated that hollow stem augers would be used to obtain the soil sample, but the method(s) used to get the sample will have to be tailored to the actual depth to be sampled.

If practical and deemed appropriate, vacuum lysimeters may be set in the auger holes after soil samples are taken so that subsequent samples of pore water may also be retrieved for analysis.

#### E.6.8 DESCRIPTION OF SAMPLING AND ANALYSIS PROCEDURES

##### E.6.8.1 SAMPLING PROCEDURES

Pursuant to 40 CFR 264.97(d), ESII has developed sampling procedures designed to collect the most representative sample possible from the groundwater aquifer under the site. The sampling procedure includes the following elements:

- o Sample collection
- o Sample preservation and handling
- o Chain-of-custody control
- o Analytical procedures

- o Field and laboratory quality assurance/quality control

#### E.6.8.1.1 Sample Collection

##### E.6.8.1.1.1 Measurement of Static Water Level Elevation.

Prior to purging or sampling the well, the elevation of the groundwater will be determined, as required by 40 CFR 264.97(f). The well identification is welded onto the well cap. The well cap will be unlocked and removed, the inner well casing cover will be removed on the bailed wells, and the bailers will be removed.

An electric tape water-level measuring device will be used to determine the depth to groundwater. Prior to lowering the probe down the well, the end of the probe that will contact the water will be rinsed with distilled water to remove any potential contamination. For the bailed wells, the probe will simply be lowered down the inner casing. For the pumped wells, an access port is provided on top of the casing cap. The probe will be lowered through this access port and down a 3/4-inch PVC pipe that extends down to groundwater. This pipe is designed to prevent the probe from becoming tangled in the pump piping and electrical wire in these wells. Once the depth to groundwater is determined, the probe will be removed from the well and the end of the probe will again be rinsed with distilled water to remove any potential contamination. Groundwater elevations will be measured to the nearest inch. Depth to the bottom of the well will not be measured except during well maintenance activities since it is available in site documents (see Table E.3-2 and Appendix B).

The well elevation relative to mean sea level has been surveyed by a registered surveyor. It has been related to a fixed reference point on the well casing. When the water

table map is reevaluated annually as required in 40 CFR 264, the measured water levels will be converted to elevations and used in this determination.

E.6.8.1.1.2 Well Evacuation. Once the groundwater elevation has been determined, the well will be purged prior to sampling. These wells are used for monitoring only and are typically not pumped between sampling events.

While water within the screened portions of a nonpumping well may experience a continued exchange with formation water due to natural flow within an aquifer, limited vertical mixing of water occurs in the casing above the screens. Thus, water standing within a nonpumping well will tend to stratify and stagnate with time. Stagnant water in a monitoring well can develop substantially different chemical characteristics than groundwater in the formation surrounding the well.

Changes in the concentration of dissolved gases in the water within the well can occur. This is caused by exchange of gases across the interface between water and the atmosphere within the well. The result can be change in redox conditions and pH in the well. This change can be accompanied by changes in the chemical species present, precipitation or dissolution of metals, and the removal or addition of constituents due to subsequent sorption reactions.

The chemical quality of water standing in contact with well materials, such as the casing, screen, or grouting, for long periods of time may also be altered by leaching or adsorption of constituents from those materials. Biological activity within the well may affect certain chemical parameters as well. A common example would be sulfate reducing or iron bacteria that can be responsible for the formation of iron sulfide and iron hydroxide in the well. These compounds may

then adsorb selected constituents. Biological activity may also be responsible for the degradation of certain biological constituents.

Because of the changes that could potentially occur as described above, all wells being sampled will first be purged. The RCRA Permit Writer's Manual for 40 CFR Subpart F (10/4/83) recommends evacuating monitoring wells to dryness if possible. Therefore, the bailed wells will be bailed dry and allowed to recover before sampling. The bailing cable is vinyl-coated and will be cleaned between use in each well. The lower-yielding pumped wells will be pumped dry and allowed to recover before sampling. The number of bails required to bail the well dry and the time required to pump the low-yielding wells dry will also be recorded. Each bailed well has a dedicated bailer and each pumped well has dedicated pump. Therefore, cross contamination that could result from using the same equipment in the purging operation is avoided. The bottom-valve bailers are 20 feet long and 2 inches in diameter and are constructed of PVC. The pumps installed in the pumped wells are Grundfos all-stainless-steel submersible pumps, Type SP1, Model SP1-16, 1/2 horsepower. The location of the pumps in each of the wells is shown in Appendix B.

Water evacuated from the wells will be allowed to discharge onto the site. The topography does not allow the water to run off the site. Those wells that can be evacuated to dryness will be purged only one time. Therefore, parameters such as pH or specific conductivity will not be monitored to establish well stabilization. This purging procedure will be maintained throughout the sampling program.

For those pumped wells that cannot be evacuated to dryness, three well volumes will be evacuated to purge the well. To

accomplish this, a determination of the sustainable yield of each well will be made. The volume of the well will be based on the amount of water in the well at the highest water-level measurement on record for that well. The amount of time necessary to purge three well volumes will be based on the maximum well volume and the sustainable yield for each well.

E.6.8.1.1.3 Sample Collection. Pursuant to 40 CFR 264.97(d) (1) and (2), sample collection procedures are described below. After the wells have been purged and allowed to recover (typically one to 2 hours), they will be sampled. For wells that cannot be pumped dry, samples will be collected immediately after three well volumes have been removed. Samples will be collected by the same techniques that are used to purge the wells. That is, the bailers will be used to collect the samples from the bailed wells, and the pumps will be used to pump water into the sample containers in pumped wells. Since each well has either a dedicated pump or bailer, cross contamination will be avoided. Therefore, the only foreign material that the water will come in contact with other than the sample containers will be the PVC piping associated with the pumps, bailers, and the vinyl-coated bailer wire. Sampling will be conducted by a qualified third party.

When collecting samples, the sample containers used for volatile constituents will be filled first. These samples will be collected to minimize agitation or aeration to prevent loss of the constituent during the sample collection process. Bailers will be lowered carefully into the water to prevent degassing of the water upon impact, and the pumping rate for the pumped wells will be throttled back so a slow, steady, nonaerated stream of water is available for filling sample containers.

E.6.8.1.1.4 Field Measurements. Three parameters--temperature, pH, and specific conductivity--will be measured in the field.

Water for these determinations will be collected in pre-rinsed one-gallon bottles. An aliquot of this water will be used for each determination. This aliquot will then be disposed of onsite. Therefore, cross contamination will be avoided.

Normal laboratory procedures will be followed in measuring these parameters; that is, all meters will be allowed to warm up before being used. The pH meter will be standardized with pH 7 and 10 buffers. The meter will also be corrected for temperature before the pH is read. The pH standardization will be determined repeatedly until the reading agrees within 0.1 pH unit.

The conductivity meter will be calibrated within 0.01 N KCl before use. The temperature of the sample will be measured as soon as it is collected.

#### E.6.8.1.2 Sample Preservation and Handling

A contract laboratory will provide the sample containers and preservatives required for the sampling event. All sample bottle preconditioning, such as baking or acid washing, will be done by the contract laboratory. Appendix H shows the type of sample containers and preservation techniques that will be used. This table is taken directly from EPA's RCRA Groundwater QA/QC Compliance Checklist (Appendix A), Revision 04-10-84, and is consistent with SW-846, Section 1.4.6.2.3. The volumes shown in the table are minimum volumes. Larger sample containers may be used.

All samples will be preserved in the field except those that must be filtered first. Metal samples must be filtered before preservation and shipment. For these samples, water will be collected in one-gallon bottles. The water will be filtered

onsite using 0.45-micron filters, preserved with nitric acid, and placed into the shipping shuttles. The sampling procedures described above will be consistent throughout the sampling program. In addition to the well samples, the sampling will also include the use of field blanks and trip blanks. These are discussed in the QA/QC section.

#### E.6.8.1.3 Chain-of-Custody Control

As required by 40 CFR 264.97(d)(4), the groundwater monitoring program will include chain-of-custody control to ensure against contamination of samples. ESII will use existing chain-of-custody record forms that are equivalent to the EPA Office of Enforcement chain-of-custody forms and the chain-of-custody form found in SW-846.

The sequence of events for controlling chain of custody will be as follows: When the sample bottles are delivered from the laboratory, the sender and receiver both sign and date the chain-of-custody form and specify on the form what has changed hands. From that point on, every time the sample bottles, whether empty or full, change hands, both parties sign and date the transfer. When sample bottles are delivered to the laboratory, a copy of the chain-of-custody form will be retained for ESII files. A sample chain-of-custody form is included in Appendix H.

As seen on the chain-of-custody sample form, the following information is included:

- o Sample number
- o Signature of sampler
- o Date of collection (time logged in field log book)
- o Place and address of collection
- o Type of sample

- o Number and type of container
- o Inclusive dates of possession
- o Signature of receiver

In addition to the chain-of-custody form, other components of chain of custody will include sample labels, sample seals, field log book, sample analysis request sheet, and the laboratory log book.

1. Sample Label. A sample label will be affixed to each sample bottle to provide the sample number.
  
2. Sample Seals. A seal will be affixed to each sample shipping container (not each bottle). This seal will have a serial number that corresponds to the number on the chain-of-custody form for that container. The seal will be secured to the locking mechanism of the shipping container immediately after sampling and will be broken at the laboratory under chain-of-custody procedures.
  
3. Field Log Book. A bound field log book will be kept for each sampling event. A copy of the field log book will be kept at the facility and will be available for inspection. The format for the field log book includes:
  - o Facility name and address
  
  - o Name and signature of sample collector
  
  - o Purpose of sample and type (for example, required analyses for initial background data, routine detection monitoring, and resampling)

- o Locations(s) or source of sampling (such as the monitoring well number)
- o Time and date of sampling
- o Pertinent well data (such as depth, water surface elevation, pumping schedule, and method)
- o Sampling method (for example, bailer, suction-lift)
- o Log number of each sample
- o Appearance of each sample (such as color, turbidity, sediment, and oil on surface)
- o Field observations/sampling conditions (such as weather)
- o Sample temperature upon sampling
- o Analyses performed in the field
  - pH
  - Specific conductance
  - Others
- o Sample storage (such as where and how; conditions such as heat and light; and number of sample seals)
- o Name and location of laboratory performing analyses

4. Sample Analysis Request Sheet. Analysis request sheets will be provided to the laboratory, with a copy kept with the field log book.
5. Laboratory Log Book. Laboratory control records will be attached to the chain-of-custody form and a copy is kept at the facility.

E.6.8.1.3.1 Sample Packing and Shipment. Once all of the samples are collected, prepared, and the chain-of-custody forms are filled out, the samples will be prepared for shipment. The sample containers will be packed with styrofoam inside the shipping shuttles along with the chain-of-custody forms. Frozen blue ice or similar material will also be placed in the shuttle in order to keep the samples cold. The shuttle lids will then be secured and sealed with a chain-of-custody tag. The shuttles will then be shipped to the contract laboratory for analysis. The sample analysis request form will be provided directly to the contract laboratory by ESI.

E.6.8.1.3.2 Sample Receipt. Upon receipt of the samples at the contract laboratory, the security of the shuttles (chain-of-custody tags) will be checked. Any shuttles that have broken or missing chain-of-custody tags will be noted and reported to the facility contact. The following procedures will then be followed:

- o The sample and seal information will be checked to ensure that they match the chain-of-custody record.
- o The chain-of-custody record will be checked for a signature.

- o The request of analysis from ESI's facility contact will be checked to determine the analyses requested.
- o A laboratory sample number will be assigned.
- o The sample will then be stored in a secure area to await analysis.

#### E.6.8.1.4 Analytical Procedures

The analytical procedures for groundwater quality analyses are summarized in Appendix H [40 CFR 264.97(d)(3)]. These procedures are identical to procedures outlined in EPA Document SW-846.

Detection limits will equal or exceed (are lower than) detection limits reported in SW-846 and are reported in Appendix H.

#### E.6.8.1.5 Quality Assurance/Quality Control

The objective of quality assurance and quality control is to assure that groundwater analytical results truly represent groundwater chemical and physical composition from groundwater sampling through analytical report preparation.

- o Overall quality assurance will be the responsibility of the Manager of Geosciences of ESI. Figure E.6-3 shows a flow chart that identifies QA/QC activities and responsibilities.
- o In summary, the sampling, analysis, and reporting of data to EPA-Region X will be the responsibility of the General Manager of ESII, his designated agents, the ESI Manager of Geosciences, the ESI

Larry Haack  
General Manager

Neil Brill  
Manager - Regulatory Affairs  
Facility Contact

Robert D. Buller  
Manager - Geosciences

Analysis Request Forms  
and  
Sample Container Receiving  
ESII

Well Sampling

- Field Measurement
- Log Book
- Chain of Custody

Well Purging

- Purging Wells
- Well Maintenance

Analytical Lab

- Sample Container Shipping
- Analysis
- QA/QC on Lab
- Report Preparation
- Chain of Custody

FIGURE E.6-3  
QUALITY ASSURANCE  
FLOW CHART



Manager of Regulatory Affairs, or others as designated by the Senior Vice President of Environmental Affairs. Actual coordination of QA/QC activities will be through ESI. ESI will be responsible for the QA/QC activities of the samplers, drillers, and analytical laboratories.

Components of the QA/QC program are as follows:

- o Laboratory: The analytical laboratory will provide all shipping containers, sampling containers and preservatives, chain-of-custody forms, labels, and seals. An example of the laboratory QA/QC procedures is included in Appendix H. This appendix illustrates the level of detail that laboratory QA/QC reporting will achieve. A full laboratory QA/QC report will accompany each data report and will be kept on file at the facility.
  
- o Sample Collection: QA/QC procedures for sample collection will be accomplished by the sampling consultant under the supervision of the ESII facility contact. A standardized field log book will be kept for each sampling event following the format described in the preceding chain-of-custody section. It will include all label and seal numbers and documentations of all QA/QC procedures related to sample collection.

It will be standard procedure to include field, lab, and trip blanks, and blind and spiked samples in each sampling event for appropriate parameters.

- Field Blanks. Field blanks will consist of a separate set of sample containers, preservatives,

and chain-of-custody forms. The containers will be opened during routine sampling and sealed upon completion of sampling. The water in the containers (ultrapure water provided by the laboratory) will have been exposed to ambient conditions to which the groundwater samples were subjected. Field blanks will be used to assess the potential for externally introduced error factors during the sampling event.

- Trip blanks. Trip blanks will accompany each sealed sample container. They will be analyzed for volatiles to assess the level of potential contamination that may have occurred during sample transport.
  
  - Lab blanks. Analysis of the water used to prepare the field and trip blank containers will be completed. This water has never left the laboratory. Lab blank data are used to establish the baseline quality of water used in all of the QC/QA blanks.
  
  - Blind and spiked samples. Standard procedures for spiking samples and replicate analyses are covered in Appendix H.
- o QA/QC of Raw Data: Another important component of the QA/QC program is the evaluation of the analytical data as reported by the analytical laboratory. The raw data as reported will be reviewed to make sure that it is correct and accurately reported. Where LT (less than) or "<" is used relative to the MDL (minimum detection level), the value used

for statistical or trend analysis will be one-half the reported value.

If indicator parameter data are missing, the following procedures will be followed:

- If one-quarter of indicator parameter data are missing from a well, values obtained during the other three-quarters will be averaged, and the averaged used as the missing quarter's value.
- If missing replicates for indicator parameters occur, the average of replicates available will be used as the missing replicate value.

The issue of outliers will be evaluated using trend line graphical procedures. If outliers are identified and can be adequately documented, they will be deleted from the data base. Trend line graphs will be prepared for all wells for indicator parameters and other chemical constituents at the discretion of ESII.

Additional QA/QC data evaluation procedures will be routinely performed and documented in the facility files as needed. These activities include review of all aspects of sampling, analysis, and data reporting.

#### E.6.8.2 STATISTICAL ANALYSIS

Pursuant to 40 CFR 264.97(h)(1)(i), after each quarterly sampling event, statistical analyses will be used to compare the most current groundwater contaminant indicator data from

the downgradient wells to the existing body of background data for the upgradient wells for both aquifers.

These analyses are designed to provide an early indication of potential migration of hazardous constituents at the down-gradient monitoring wells located on the point of compliance. It is clear that any procedure used to assess the impact of a facility's operation on the uppermost aquifer must be able to meet the following characteristics:

1. The procedure must be able to discern between naturally occurring variations in water quality and migration of waste constituents released from the facility.
2. The procedure should use all available data from all wells in the same monitoring system when comparisons are made in order to maximize the power of the test.
3. All values must be collected independently of each other.

#### E.6.8.2.1 t-Statistics

40 CFR 264.97(h) (1) specifies that the owner or operator use the Cochran's Approximation to the Behrens-Fisher Student's t-test (CABF) or an equivalent statistical procedure be used to determine whether a statistically significant change has occurred in water quality at the point of compliance as compared to background data.

The averaged replicate (AR) t-test methodology is presented for several reasons. First, the AR t-test has been suggested for use in public comment and was recommended subsequently

for use in a memorandum from Skinner in November 1983. Also, the AR t-test removes the heavy influence that split sample or replicate variability exerts on the overall estimate of variability in the background data. It has been suggested that the AR t-test may help alleviate statistical contributions to the problem of incorrect indication of contamination frequently caused when using the CABF method.

#### Methodology Used to Analyze the First Year's Data

The background mean and variance must be calculated. This is done by first averaging the replicate measurements and then using these replicate averages to calculate the background mean and variance as described below.

Background Mean:

$$\bar{X}_{ij} = \sum_{k=1}^{p_b} (X_{ijk}/p_b)$$

$$\bar{X}_b = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} (\bar{X}_{ij}/M_b)$$

Where:

$M_b$  = The number of samples taken during the collection of background data.  $M_b$  does not include the replicate measurement. In a complete data set  $M_b$  is equal to  $n_b$  times  $o_b$ .

Background Variance:

$$s_b^2 = \sum_{i=1}^{n_b} \sum_{j=1}^{o_b} (\bar{X}_{ij} - \bar{X}_b) / M_b - 1$$

Methodology Used to Analyze Data Collected After the First Year

The requirements and objectives of sampling after the first year are the same regardless of the test being applied. For the AR t-test only the average concentration for each well ( $\bar{X}_m$ ) is used in the calculation of the t-test. A description of the sampling requirements and method for calculating  $\bar{X}_m$  are described in the prior section for the CABF test. No variance is computed for the monitoring data collected after the first year when using the AR test.

The AR t-statistic is calculated as follows:

$$t^* = \frac{\bar{X}_m - \bar{X}_b}{s_b^2 \sqrt{1 - 1/M_b}}$$

The critical statistic ( $t_c$ ) is obtained directly from the following table, adapted from Table 10 of Biometrika Tables for Statisticians, Volume 1, 1954, by permission of E. S. Pearson and the Biometrika Trustees.

Table E.6-1  
ONE AND TWO TAILED CRITICAL t VALUES  
AT THE 0.05 LEVEL OF SIGNIFICANCE

<u>Degrees of Freedom</u>	<u>One Tailed</u>	<u>Two Tailed</u>
1	6.31	12.7
2	2.92	4.30
3	2.35	3.18
4	2.13	2.78
5	2.02	2.57
6	1.94	2.45
7	1.90	2.37
8	1.86	2.31
9	1.83	2.26
10	1.81	2.23
11	1.80	2.20
12	1.78	2.18
13	1.77	2.16
14	1.76	2.15
15	1.75	2.13
16	1.75	2.12
17	1.74	2.11
18	1.73	2.10
19	1.73	2.09
20	1.73	2.09
21	1.72	2.08
22	1.72	2.07
23	1.71	2.07
24	1.71	2.06
25	1.71	2.06
26	1.71	2.06
27	1.70	2.05
28	1.70	2.05
29	1.70	2.05
30	1.70	2.04
40	1.68	2.02
$\infty$	1.65	1.96

The  $t_c$  is the value from the above table that corresponds to  $M_b - 1$  degrees of freedom, when  $M_b =$  the number of samples taken during the collection of background data, exclusive of replicate measurements.

The  $t^*$  and  $t_c$  values are compared using the following decision rules:

- o If specific conductivity, TOC, and TOX are being evaluated and if  $t^*$  is less than  $t_c$ , then there is no statistical indication that the IP concentrations are larger in the well under comparison than in the background data. If  $t^*$  is larger than  $t_c$ , then there is a statistical indication that IP concentrations are larger in the well under comparison.
  
- o If pH is being evaluated and if  $|t^*|$  (which is the absolute value of  $t^*$  or  $t^*$  without a + or - sign) is less than  $t_c$ , then there is no statistical indication that pH has changed. If  $|t^*|$  is larger than  $t_c$ , then there is an indication that pH has changed statistically. If  $t^*$  is negative, then pH increased; if  $t^*$  is positive, pH decreased.

The advantage of the AR method is that less computational effort is required; hence, the test is simpler and easier to use and understand, and the variance among replicate samples is eliminated as a source of statistical error, reducing the chance of a "false-positive."

#### E.6.8.2.2 Equivalent Statistics

40 CFR 264.97(h) (1) (ii) specifies that "The owner or operator may use an equivalent statistical procedure for determining whether a statistically significant change has occurred.

The Regional Administrator will specify such a procedure in the facility permit if he finds that the alternative procedure reasonably balances the probability of falsely identifying a noncontaminating regulated unit and the probability of

failing to identify a contaminating regulated unit in a manner that is comparable to that of the statistical procedure described in paragraph (h) (1) (i) of this section." In response to this regulation, ESII is proposing to also use a statistical procedure that is more appropriate to statistical analysis of groundwater data, Analysis of Covariance.

#### E.6.8.2.3 Analysis of Covariance (ANCOVA)

The ANCOVA procedure is recognized as a more appropriate statistical procedure than the t-test for analyzing groundwater data. It eliminates several biases that are built into the t-test and how it has been applied to statistical analysis of groundwater data in the regulations because it does not assume that groundwater data should be homogeneous over time and at all locations.

The analysis of covariance provides the following desirable characteristics:

- o Use of all the available relevant data
- o Holding temporal variation constant
- o Taking proper account of spatial variation
- o Maximizing statistical power

In addition, analysis of covariance has the advantages of being well documented in widely distributed textbooks (Ott, 1984) and of being available in all of the most used computer software statistical analysis packages (e.g., SAS BMDP, SPS).

The ANCOVA is a procedure that combines features of analysis of variance and regression analysis. The procedure first removes the effects of a covariable (in the present case, time, or quarter) from the values of the dependent variable and then performs an analysis of variance on the residuals.

These residuals may be thought of as the values that would have been obtained if all of the data had been obtained at the same time (i.e., if there had been no seasonal variation).

Therefore, the analysis of covariance can be used to test for differences between upgradient and downgradient wells with quarter (season) used as a covariance. This approach has three advantages. First, since it removes seasonal variation from the error term (standard error squared), there is a substantial increase in statistical power. Second, since only a single test is needed, the nominal alpha and the actual alpha are the same. Third, since all of the data available are used for each test, there is a further increase in power as a result of the substantially increased number of degrees of freedom.

ESII will use the ANCOVA statistical procedure to compare all upgradient well data to all downgradient well data in the same aquifer at the 95 percent confidence level. This will allow detection of any significant differences in upgradient versus downgradient water quality resulting from migration of hazardous constituent indicators to the uppermost aquifer from the facility's regulated units.

The basis for using ANCOVA is that there are two groups of relevant data: upgradient water quality data and downgradient water quality data. The ANCOVA procedure works by estimating the random variation within a group and comparing this to the observed variation among group means. The working hypothesis is that for there to be a statistically significant difference, the variances between the downgradient and upgradient wells ought to be greater than the variances between the wells within each of the two groups.

The variance within groups is calculated as:

$$\frac{1}{a(N-1)} \sum_{i=1}^{i=a} \sum_{J=1}^{J=N} (Y_{ij} - \bar{Y}_i)^2$$

Where: a = number of groups

The resulting calculation yields the average variance within groups.

The second estimation is for variance between groups means:

$$\frac{N}{a-1} \sum_{i=1}^{i=a} (\bar{Y}_i - \bar{\bar{Y}})^2$$

Where:  $\bar{\bar{Y}}$  = mean of group means, or "grand" mean

Both estimates of variance, i.e., the variance within groups and between groups, are independent.

The variances among groups and within groups are next compared using the F distribution. The F-value estimated from sample variances is calculated as follows:

$$F_2 = \frac{S_1^2}{S_2^2}$$

Where:  $S_1^2$  represents the variation between the upgradient mean and the downgradient mean

$S_2^2$  is an estimate of the amount of variation expected by random sampling

If that ratio is approximately one, then the upgradient mean does not differ from the downgradient mean by more than what would be expected by random chance. If the ratio is much greater than one, it indicates a possible impact on ground-water quality. The square root of this test is a Student's  $t$ , where the changes in  $F$  are equal to those associated with  $S_2^2$ , random sampling variations.

This additive effect will be reflected in the statistical test as follows for the variance within the groups:

$$\frac{1}{a(N-1)} \sum_{i=1}^{i=a} \sum_{J=1}^{J=N} [(Y_{ij} + a'_i) - (\bar{Y}_i + a'_i)]^2$$

Where:  $a'$  = the effect of hazardous constituent migration

The variance within groups reduces to:

$$\frac{1}{a(N-1)} \sum_{i=1}^{i=a} \sum_{J=1}^{J=N} [(Y_{ij} - \bar{Y}_i) + (a'_i - a'_i)]^2$$

which further reduces to:

$$\frac{1}{a(N-1)} \sum_{i=1}^{i=a} \sum_{J=1}^{J=N} (Y_{ij} - \bar{Y}_i)^2$$

Note that the effect of adding  $a'$  to a group is that of a constant, since  $a'$  is additive and additive codes do not affect sums of squares or variances. Therefore, no effect of contamination would be seen in the group variance. However, since the means of the individual groups will change because of the effect of contamination, the variance among groups (upgradient versus downgradient) will also be affected:

$$\left( \left( \frac{1}{a-1} \right) \sum_{i=1}^{i=a} (\bar{Y}_i - \bar{Y})^2 \right) + \left( \left( \frac{1}{a-1} \right) \sum_{i=1}^{i=a} (a'_i - \bar{a}'_i)^2 \right) + \left( \left( \frac{2}{a+1} \right) \sum_{i=1}^{i=a} (\bar{Y}_i - Y) (a'_i - \bar{a}'_i) \right)$$

The first of these terms (1) is immediately recognized as the previous variance of means  $S_Y^2$ . The second term (2) is the variance due to any additive effect. The third term (3) is the effect of covariance on the variance among groups.

When the variance among groups, as calculated above, is divided by the variance within groups to estimate  $F_s$ , it is apparent that the F-test is sensitive to the addition of the effects of contamination and is therefore an appropriate test for groundwater quality analysis. As noted in Sokal and Rohlf, 1969, page 191, this test will enable the facility "to test whether there are added treatment effects--that is, whether a group of means can simply be considered random samples from the same population or whether treatments which have affected each group separately have resulted in shifting these means sufficiently so that they can no longer be considered samples from the same population. If that is so, an added component due to treatment effects will be present and may be detected by an F-test..."

The third factor is the formula given above, the effect of covariance, is the factor that enables this procedure to estimate and subtract out the effect of variability due to temporal variations in parameter values. The effects of spatial differentiation is considered to be random effect that does not affect group means and hence is not included in the estimate of among-group variance. (That is, spatial effects do not bias the results of analysis.)

The above procedure will be applied using the SAS statistical package available through the SAS Institute. The computer

software package is proprietary information and is reserved by the SAS Institute. The following programming statements are applicable to the utilization of SAS for ANCOVA:

Data One;	Creates a data set called "one"
Infile Sher;	Reads a file called "Sher" that looks like the data
Input Depth \$ 1 Loc \$ 2 Well-Num 4 @ 1 Well \$ Time Chem \$ X1-X4;	Reads the data from "Sher" into "one" according to the specification in the input statement
Drop X1-X4;	X1-X4 will not be retained in the data set
Con = X1; Output; Con = X2; Output; Con = X3; Output; Con = X4; Output;	These statements create separate observations for each of the four replicate values
Cards;	Signals the end of the input portion of the program
Proc Sort; By Chem;	Sorts the data by parameter, pH, TOC, etc.
Proc GLM; By Chem; Classes Well Time Loc; Model Con = Time Loc Well(Loc); Test H = Loc E = Well(Loc)/Htype = 1 Etype = 1;	These three statements cause the analysis of covariance to be conducted
Title Analysis of Covariance of Groundwater Data;	Self-explanatory

The program statements specific to the needs of this facility's Groundwater Monitoring Program will be developed when the permit conditions relative to the groundwater monitoring program are finalized.

#### E.6.8.2.4 Implementation of Statistical Analysis

As described in previous sections, two distinct statistical procedures are proposed: the method mandated in the regulations (CABF) and the equivalent alternative method (ANCOVA). The two methods, although quite different in approach, will both use the same data base drawn from the same wells and the same parameter list. There is a fundamental difference between the two: The CABF will use replicate analyses from each indicator parameter, whereas the ANCOVA will use no replicates. The reason for this is that the ANCOVA requires

that all values to be used in the analysis must be independent of each other. This is a fundamental requirement of this (and any applicable) statistical test. Therefore, to use replicates would invalidate the procedure. As previously stated, replicates measure lab bench error only, so the use of single data points would not only preserve the ability to use ANCOVA, but would also eliminate a source of error not related to groundwater quality.

Once the collection of quarterly background data commences, four quarters of data will be collected from each of the wells in the monitoring program. Beginning with the fifth quarter and semi-annually thereafter, both statistical procedures will be applied.

The time needed from completion of sampling to the completion of the statistical examination of the data is estimated to be 90 to 120 days. The turnaround time for the laboratory analyses and data verification is approximately 60 to 90 days and the statistical evaluation of the results is estimated to take 30 days.

If a statistically significant increase is confirmed by both the AR and the ANCOVA procedures, the Regional Administrator will be notified in writing of this finding within 7 days.

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